Department of Science, Information Technology and Innovation

Consistent Climate Scenarios User Guide

AR4 ‘Change factor’ and ‘Quantile-matching’ based climate projections data

Grazing Land Systems – Science Delivery

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Queensland Government

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About this document

The intent of this User Guide is to provide users (previously restricted to project teams under the CCRP program (see Appendix), but now extended to all users) with background input and guidelines for using the Consistent Climate Scenarios (CCS) projections data. The User Guide aims to assist users in interpreting the data that has been provided.

This updated User Guide (V2.2) which supersedes the previous draft (V2.1) released in August 2012, includes additional information about:

- the availability of CCS datasets through the Long Paddock Climate Change Projections web portal
- updated CF and QM file-naming conventions
- additional projections data for four Representative Future Climate partitions (RFCs)
- maps showing projected 21st Century temperature changes for the four RFCs

This User Guide was supported by the project's Chair and Expert Panel. In addition, User feedback has also played an important role in the development and improvement of the information that this User Guide contains.

Referencing Consistent Climate Scenarios (CCS) Data

The data source should be acknowledged as the Queensland Government SILO database (http://www.longpaddock.qld.gov.au/silo). The SILO database is operated by DSITI.

The climate 'change factors' used to calculate CCS data have been estimated using:

- Coupled Model Intercomparison Research Program 3 (CMIP3) patterns of change data (projected changes per degree of 21st Century global warming) supplied by the CSIRO and the UK Met Office/Hadley Centre; and
- data from AR4 SRES scenario temperature response curves (projected amounts of global warming) supplied by the CSIRO.

As such, the following data sources should also be acknowledged:

- The CMIP3 global model database (http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php)
- OzClim http://www.csiro.au/ozclim)
- UK Met Office/Hadley Centre (http://www.metoffice.gov.uk/climate-change/resources/hadley)

Related publications

Further information, describing the infilling of trends per degree of global warming for missing climate variables, is documented in:

Ricketts, J.H[a]., Kokic, P.N[b]. and Carter, J.O[a]. (2011). Estimating trends in monthly maximum and minimum temperatures in GCMs for which these data are not archived. [a]Queensland Climate Change Centre of Excellence, Queensland Government. [b]CSIRO, Mathematics, Informatics and Statistics. 19th International Congress on Modelling and Simulation (MODSIM), Perth, Australia 12-16 December 2011, http://www.mssanz.org.au/modsim2011/F5/ricketts.pdf.

Further information, describing the 'quantile-matching' approach, is documented in:

Kokic, P., Jin, H. and Crimp, S. (2012). Statistical Forecasts of Observational Climate Data. Extended Abstract, International conference on "Opportunities and Challenges in Monsoon Prediction in a Changing Climate" (OCHAMP-2012), Pune, India 21-25 February 2012.

Additional information, summarising the Consistent Climate Scenarios Project, is documented in:

Ricketts, J.H[a]., Kokic, P.N[b]. and Carter, J.O[a]. (2013). Consistent Climate Scenarios: projecting representative future daily climate from global climate models based on historical data. [a]Department of Science, Information Technology, Innovation and the Arts. Queensland Government. [b]CSIRO, Mathematics, Informatics and Statistics, Australia. 20th International Congress on Modelling and Simulation (MODSIM), Adelaide, Australia, 1–6 December 2013, http://www.mssanz.org.au/modsim2013/L11/ricketts.pdf.

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1 Introduction

Researchers conducting studies of climate change impacts on primary industries have previously not had access to a consistent set of climate change projections in a suitable format for use in biophysical models.

The aim of the Consistent Climate Scenarios Project (CCSP) has been to develop a consistent set of synthetic climate projections data across Australia for use in biophysical models, which maintain 'weather-like' properties and also account for uncertainties and biases in climate change projections, as well as different methods of downscaling.

Since July 2012, the CCSP has been delivering a consistent set of model-ready (AR4-based) 2030 and 2050 Australia-wide climate change projections data, via the Long Paddock website's Climate Change Projections web portal http://www.longpaddock.qld.gov.au/climateprojections/.

The first phase of the project used CSIRO's OzClimTM 'change factor' (CF) approach (described in Section 4) to transform historical climate data, based on projections information from CSIRO's OzClim tool. CF (Version 1) projections data were released for eight Global Climate Models (GCMs) in September 2010, followed by CF (Version 1.1) projections data for 17 GCMs in April 2011. As at April 30, 2012, a considerable amount of CF (Version 1.1) projections data had been provided to end-users, exceeding 650 individual Australian locations, 1.3 million data files and 850GB data volume. The latest version of the CF projections data (V1.2), released in June 2012, is the same as V1.1, except that it now includes data for two highly ranked Hadley Centre GCMs (HADCM3 and HADGEM1) and has been adapted for delivery via the Long Paddock website's Climate Change Projections web portal.

The second phase of the project, which incorporated a more sophisticated approach called 'quantile-matching' (QM, see Section 5), supplied by Dr Phil Kokic and Mr Steven Crimp (CSIRO), was implemented and enhanced by Dr Andrej Panjkov (QCCCE). QM considers projected changes in the cumulative distribution function of the climate projections (Kokic *et al*. 2012). The method used to calculate the 2030 projections data (Version QMV2.2.0 released in June 2011, updated to Version QMV3.0 in May 2015) does this by incorporating significant observed trends in 10th, 50th and 90th percentile values that have been extrapolated to 2030. QM 2030 projections are available for the same GCMs as the CF data. QM 2030 projections data are also available via the Climate Change Projections web portal.

A variation in the QM method, to incorporate daily GCM data, has been used to calculate QM based projections data for 2050 (Version QM2.2.10, 2050, released mid-November 2011). The QM 2050 projections, which were limited to a single GCM, due to the availability of raw daily GCM data for 2050, are available via: ftp://climate.mft.derm.qld.gov.au/Climate_Scenarios/QM_2050_TestData/.

Users are encouraged to consider the limitations of both the CF and QM approaches when interpreting model output based on these climate change projections data.

Figure 1.1 indicates the relationship between the CCSP partners and their roles in delivering the project outputs. Table 1.1 presents the CCSP versioning.

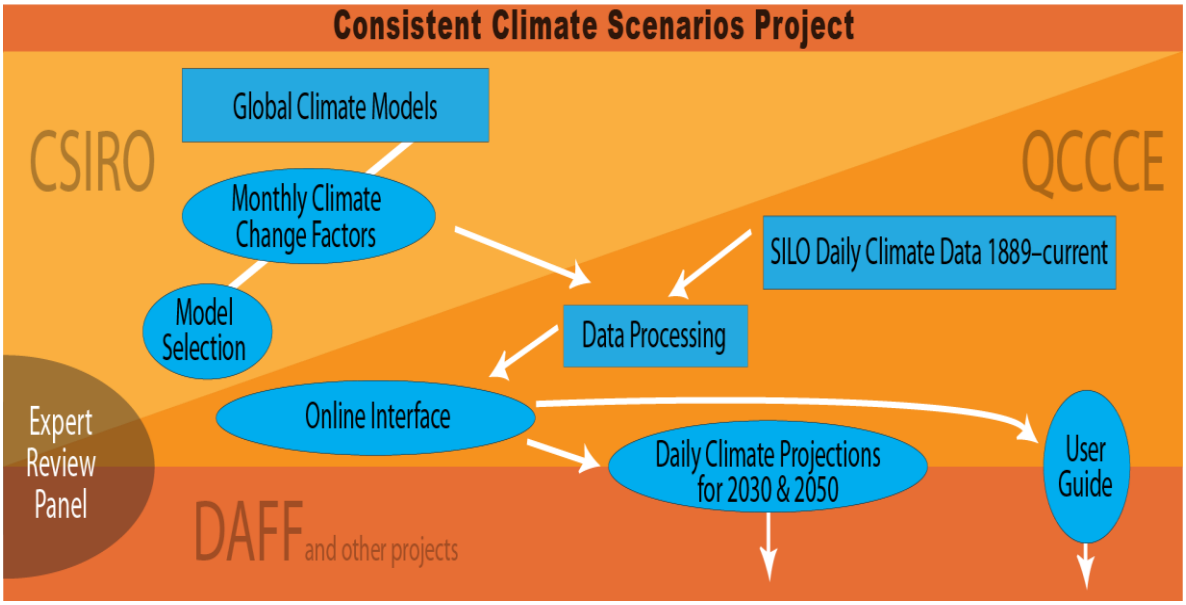


Figure 1.1 Relationships between Consistent Climate Scenarios Project partners and project outputs.

In the AR4 CCS projections data, 2030 (or 2050) represents a period (e.g. 30 years) centred on that year. The length of the period will be the same as the user's selected SILO historical base period.

For applications model evaluation, we recommend usage of a 1960-2010 base period (the quality of post-1960 historical climate data is higher than that of earlier data). The period from 1960 to 2010 also encompasses a wide range of natural climate variability (i.e. droughts and floods) due to fluctuations in the El Niño Southern Oscillation phenomenon (ENSO), as well as opposite phases of the Interdecadal Pacific Oscillation (IPO).

Table 1.1 Consistent Climate Scenarios Project Versioning

Product	Version	Release date	Comments
'Change factor' (CF) data These files have no method tag.	V0	Apr 2010	Initial CF 2030 and 2050 projections test data for format checks, etc.
	V1	Sep 2010	Eight GCMs, eight emissions scenarios, three climate sensitivities, six climate variables and two projections years (2030 and 2050).
	V1.1	Apr 2011	17 GCMs, eight emissions scenarios, three climate sensitivities, six climate variables and two projections years (2030 and 2050). Some improvements on evaporation. Historical baseline 1899 to current.
	V1.2	Jun 2012	This is the version running under the web. Historical baseline 1960-2010. Includes two Hadley Centre GCMs (HADCM3 and HADGEM1). Otherwise, there is no difference in the data, from that of V1.1.
'Quantile-matching' (QM) data These files have a QM method tag in the filename.	QMV2.1.0 2030 **QM in filename**	Jun 2011	Initial 2030 test set.
	QMV2.2.0 2030 **2030 & QMv2.2 in filename**	Jul 2011	Initially 17 GCMs, eight emissions scenarios, three climate sensitivities, six climate variables and one projections year (2030). Two extra GCMs (HADCM3, HADGEM1 added for the web version in June 2012.
	QMV3.0 2030 **2030 & QMv3.0 in filename**	May 2015	Code adjusted to fix a trivial error in QMV2.2.0, for which an insignificant amount of daily rainfall data had been affected and to negligible extent.
	QMV2.2.10 2050 **2050 & QM2.2 in filename**	Nov 2011	2050 only. Limited to a 52 station test set, for a single GCM (ECHAM 5), one emissions scenario (A1B) and one climate sensitivity (median). Approach for 2050 rainfall and temperature projections uses daily GCM data. Projections for other climate variables based on QM 2030 method extended to 2050. 2050_QM2.2 in filename, but internally known as QMV2.2.10, to reflect different data, available via ftp://climate.mft.derm.qld.gov.au/Climate_Scenarios/QM_2050_TestData/
User Guide	V1.0	Nov 2010	Development version, supporting 'change factor'(V1) data for eight GCMs.
	V1.1	May 2011	Development version, supporting CF V1.1 data for 17 GCMs.
	V2	Oct 2011	Information added to support QM 2030 test set. Includes CF and QM 2030 methodologies.
	V2.1	Aug 2012	Information added to support HADCM3 and HADGEM1 GCMs, CF V1.2 and QM 2050 data sets, updated filenames, descriptions for QM trend plots and QM 2050 methodology. Brief notes about transient data sets, the Climate Change Projections data interactive web portal and the ftp site.
	V2.2	May 2015	Additional information on the availability of CCS datasets through the web portal, updated file-naming conventions (Section 2) and projections data for four Representative Future Climate partitions (Section 8).
Web-based data portal		Aug 2012	http://longpaddock.qld.gov.au/climateprojections/ Portal on the Long Paddock website, from which requests for CCS projections data can be made.

2 Accessing and interpreting data

What is available?

The 2030 and 2050 daily (AR4-based) climate projections data are available for six climate variables useful for biological modelling, including:

- rainfall
- maximum and minimum temperature
- solar radiation
- vapour pressure
- pan evaporation.

Users can order projections data based on:

- the 'Change factor' or 'Quantile-matching' method (see Sections 4 and 5)
- eight emissions scenarios (see Section 7.1)
- three climate warming sensitivities (see Section 7.3)
- 19 global climate models (see Section 8).

Registration

The climate projections data are password protected. To access to these data, a new user must complete and submit the registration form at:

http://www.longpaddock.qld.gov.au/climateprojections/registration.php

Login details are provided by email, once registered (allow three working-days).

Ordering data

The climate projections data can be ordered by clicking the **REQUEST DATA** link at:

http://www.longpaddock.qld.gov.au/climateprojections/registration.php

Home → Climate change projections →
Data access
Consistent Climate Scenarios data are currently supplied free of charge. However, all users must be registered. A free sample of the data (ZIP, 1.3M, last updated 03:00PM, 14 May 2012) is available for testing without being registered.
To register for data access, please fill out and submit the registration form. Once we have returned your registration details, you can start requesting data.
Only small orders for data can be accepted via this web site. For example, you can only download data for up to ten locations and up to three emission scenarios at any one time. If you wish to order larger amounts of data, please contact Grazing Land Systems.
REQUEST DATA

The CCS login page (Figure 2.1) will then appear:

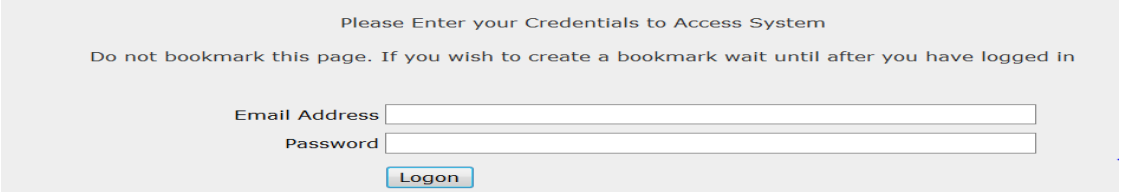

Please Enter your Credentials to Access System
Do not bookmark this page. If you wish to create a bookmark wait until after you have logged in
Email Address
Password
Logon

Figure 2.1 CCS login page.

Following login, the steps required to order data are:

Step 1: Select order type

Choose the type of data. Data can be for 'Weather stations', or point locations (by 'Latitude and Longitude'), with an option for 'Full data' (daily projections) or 'Summary data' (i.e. plots showing comparisons of GCM model projections for 2030 based on the A1B emissions scenario).

Step 2: Select weather station locations

Select the required weather stations (by station Name or ID Code), or point-locations (by latitude and longitude).

Step 3: Select data parameters

Choose 'Change factor' (CF) or 'Quantile-matching' (QM) projections, the historical baseline period (start and end years), the projections year (2030 or 2050), and choice of up to three emissions scenarios, up to three global warming sensitivities and up to 23 climate models.

- Projections data are always packaged with the following ancillary information, which can be used with or independently of the projections data:
  - historical-baseline climate data files
  - multiplier files (containing the information used to calculate 'change factors')
  - comparison of model projections plots (showing change in rainfall and temperature at 2030 for 19 GCMs based on 'change factors')
  - a CO_2 matching file (look-up table)
  - log warning files (only with CF orders).

Step 4: Select delivery details

Enter a unique label to assist in identification of the ZIP archive that will be created for your projections data files. Then select the projections data file format (APSIM or p51), option to include 'diagnostic charts' or not, and finally how you wish to receive the data (FTP is preferred).

- If 'diagnostic charts' is selected, the user will receive the following, which can be used with or independently of the projections datasets:
  - historical time series plots of histograms showing historical and 'quantile-matched' distributions for each climate variable (only with QM orders)
  - monthly quantile trend plots, for selected climate variables (only with QM orders).

Step 5: Confirm order

Your order is summarised, with an option to submit or revise it.

- Once submitted, the option is available for a user to track the progress of the order.

An example of the web portal process for ordering CCS data is provided in the Appendix. Further information is available in the '**Data Order Online Help'** page in the CCS web portal.

FTP data collection site

The user will be notified by email, as soon as the data order has been processed. The email will provide a link to the specific location of the data under 'CCCS_Web_Data_Outputs' on the FTP data collection site (Figure 2.2).

Ancillary information hosted on the FTP data collection site, includes the following:

- the User Guide
- a 52-station QM 2050 test-set (see Section 2.2), based on a single GCM, one emissions scenario and one climate sensitivity
- a single-station 1899-2100 CF-based transient data set (see Section 3.11).

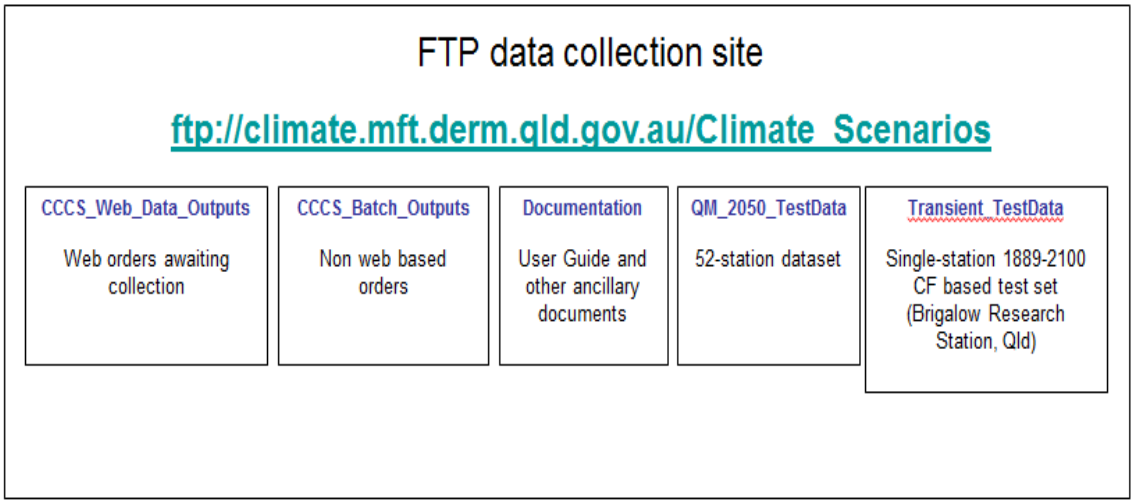


Figure 2.2 Information available at the CCS FTP Data collection site (as at May 1, 2015).

Important notes for users, regarding ZIP archives

Windows

Self-extracting ZIP archives (file extension **.zip.exe**) only work for the Windows environment. They won't work when downloaded to non-Linux/x86, Unix systems (e.g. HP-UX, AIX, Solaris, DG-UX, IRIX, TRU64, OSF/1).

Unix and Linux

Standard ZIP files (file extension **.zip**) can be provided for Unix and Linux users. Unix users can extract the projections data files by typing **unzip filename.zip** in the Unix command line.

ZIP archive file-sizes

When ordering data, the user needs to consider the size of zipped archives and the number of files that will be produced. Table 2.1 shows typical zip archive file sizes and the number of files that will be produced.

Table 2.1 Typical ZIP archive file sizes and number of files (based on the selection of the default 1960-2010 climate baseline, including diagnostic plots).

Projections type	User selection 1 location 1 GCM 1 emissions scenario 1 climate sensitivity	User selection 10 locations 1 GCM 1 emissions scenario 1 climate sensitivity	User selection 10 locations 19 GCMs 3 emissions scenarios 3 climate sensitivities
CF 2030 or 2050 projections	**0.5 MB, 5 files** 1 projections file 1 SILO file 1 multiplier file 1 CO^2 matching file 1 log file	**4.8 MB, 50 files** 10 projections files 10 SILO files 10 multiplier files 10 CO^2 matching files 10 log files	**322 MB, 2470 files** 1710 projections files 190 SILO files 190 multiplier files 190 CO^2 matching files 190 log files
CF 2030 or 2050 projections with diagnostic plots	**0.7 MB, 7 files** Includes the same files as those above, plus: 1 comparison of model projections plot 1 time series plot	**6.7 MB, 70 files** Includes the same files as those above, plus: 10 comparison of model projections plots 10 time series plots	**324 MB, 2490 files** Includes the same files as those above, plus: 10 comparison of model projections plots 10 time series plots
QM 2030 projections	**0.5 MB, 4 files** 1 projections file 1 SILO file 1 multiplier file 1 CO^2 matching file	**5.3 MB, 40 files** 10 projections files 10 SILO files 10 multiplier files 10 CO^2 matching files	**369 MB, 2280 files** 1710 projections files 190 SILO files 190 multiplier files 190 CO^2 matching files
QM 2030 projections with diagnostic plots	**5.9 MB, 17 files** Includes the same files as those above, plus: 1 comparison of model projections plot 1 time series plot 5 quantile trend plots 6 QM histogram plots	**59 MB, 170 files** Includes the same files as those above, plus: 10 comparison of model projections plots 10 time series plots 50 quantile trend plots 60 QM histogram plots	**443 MB, 2410 files** Includes the same files as those above, plus: 10 comparison of model projections plots 10 time series plots 50 quantile trend plots 60 QM histogram plots

2.1 'Change factor' (CF) data

Availability

'Change factor' (CF) based projections data can be ordered through the Long Paddock website's Climate Change Projections web portal:

http://www.longpaddock.qld.gov.au/climateprojections/.

Users have a choice of CF projections data files for 2030 and 2050, 19 GCMs (see Section 8), eight emissions scenarios (see Section 7.1) and three climate warming sensitivities (see Section 7.3). Each projections file contains projections data for six climate variables (see Section 6) using the CF methodology (see Section 4). CF projections data can be made available for any weather station or point location (latitude and longitude) within Australia.

For small orders, the average delivery time to the ftp server is 60 minutes from being submitted. For large orders, delivery time is usually within 24 hours. Users are notified by email, with a link to their data on ftp server, as soon as an order has been processed and is ready for download.

All CCS files on the ftp server are contained in ZIP format archives. Users should note that the ZIP format archives will be deleted seven days after having been processed. This is to ensure that the ftp site does not reach capacity, enabling new file-space to be created for additional orders.

CF ZIP archives - containing daily projections

CF climate projections data files (as well as historical baseline climate data files, monthly multiplier files, CO2 matching files and log warnings files) for each selected climate site are contained in a ZIP format archive named as follows:

User.name_JobNumber_FileLabel_Archivetype

e.g. john.smith_its138_FileLabel_zip.exe

- Username (derived from your email address)
- JobNumber (i.e. its138, its139, its140, etc.)
- FileLabel (1-8 character label, specified by the user, i.e. cf2030, testdata, etc.)
- Archivetype (i.e. .zip.exe *for Windows* or .zip *for Unix/Linux*)

File types packaged in CF ZIP archives containing daily projections data (including filename examples) are:

- **CF projections**
  - 051039_A1F1_2030_M_CSIRO-MK35_-31.5495_147.1961_V1.2.met (details in this Section)
- **Historical baseline climate data**
  - 051039_SILO_-31.5495_147.1961_V1.2.met (described in Section 2.3)
- **Multiplier files**
  - 051039_-31.5495_147.1961_V1.2.multiplier (described in Section 3.1)
- **CO2 matching files**
  - 051039_-31.5495_147.1961_NamesList.txt (described in Section 3.2)
- **Log warning files**
  - 051039_-31.5495_147.1961_V1.2.log (described in Section 3.4)

CF ZIP archives - containing diagnostic plots

CF 2030 diagnostic charts (which include comparison of model projections plots for 2030 based on the A1B emissions scenario and historical time series plots) for each selected climate site are contained in a ZIP format archive as follows:

User.name_JobNumber_FileLabel_Plots_Archivetype

e.g. john.smith_its138_plots_zip.exe

- Username (derived from your email address)
- JobNumber (i.e. its138, its139, its140, etc.)
- FileLabel (1-8 character label, specified by the user, i.e. cf2030, testdata, etc.)
- Plots (shows that plot files are included)
- Archivetype (i.e. .zip.exe *for Windows* or .zip *for Unix/Linux*)

File types packaged in CF ZIP archives containing diagnostics plots (including filename examples) are:

- **Comparison of model projections plots**
  - 051039_A1B_M_2030_31.5495_147.1961_mdlperf_V1.2.png (described in Section 3.7**)**
- **Historical time series plots**
  - 051039_-31.5495_147.1961_V1.2.png (described in Section 3.5)

CF Projections files

Once the ZIP archive is opened, individual CF climate projections data files and ancillary files are then accessible. The CF climate projections data files are named as follows:

LocationCode_Scenario_ProjectionsYear_ClimateWarmingSensitivity_ModelName_Latitude_Longitude_VersionNumber.SILOformat

e.g. 051039_A1FI_2030_M_CSIRO-MK35_-31.5495_147.1961_V1.2.met

- 'LocationCode' is a six digit number (BoM station code if patched-point, i.e. 051039, or all zeros if drilled (from interpolated surfaces), i.e. 000000)
- Scenario (emissions scenario[1], i.e. A1B, A1FI, etc.)
- Projections year (i.e. 2030 or 2050)
- Climate warming sensitivity (rate of global warming, i.e. L, M, H)
  - 'L', 'M' and 'H' refer to the 10th, 50th and 90th percentile values respectively.
- ModelName[2] (i.e. CSIRO-MK35, HADGEM1, HI, HP, etc.)
- Latitude and longitude of the station, or location, in decimal degrees (rounded to 4 decimal places)
- CF Version (i.e. V1.2)
- SILO format (either 'met' for APSIM or 'p51' for GRASP)

[1] Emissions scenarios and climate warming sensitivities used in the project are discussed in Section 7.

[2] More information about the AR4 GCMs and Representative Future Climate partition model composites used in this project is available in Section 8.

CF Projections file metadata

The CF projections files, in APSIM format, contain the following metadata in the first 21 rows of each file:

- **Station number**

  This is the same as the 'Location code', following the same convention as is used by the Bureau of Meteorology (BoM), which consists of six digits, containing leading zeros. For example station 51039 in the SILO database adopts the BoM station identifier convention and becomes LocationCode 051039 for this project.
- **Station name**

  'None' is listed if the location is selected by latitude and longitude.
- **Latitude and longitude** (decimal degrees)
- **Long-term annual average ambient temperature** (tav, ºC)

  Perturbed tav, based on the default period (currently 1960 to 2010).

  If 1970 to 2000 is selected, the calculation will be based on 1970 to 2000.
- **Annual amplitude in mean monthly temperature** (amp, ºC).The difference between the long-term mean of the warmest month of the year and the long-term mean of the coolest month of the year. Statistical period the same as tav.
- **The date that the projections data were computed**
- **Projections year** (2030 or 2050)
- **Emissions scenario** (Eight are available, see Section 7.1)
- **GCM model or RFC composite**

  19 Global Climate Models (see Section 8, Table 8.2) and four Representative Future Climate composites (see Section 8, Table 8.3) are available. The CCS project's file naming convention for AR4 GCMs (documented in Section 8, Table 8.2) uses abbreviations of the formal model names used by the Program for Climate Model Diagnosis and Intercomparison (PCMDI) Coupled Model Intercomparison Project phase 3 (CMIP3).
- **Model sensitivity** (low, median or high), refer to 'climate warming sensitivity' (Section 7).
- **Ambient CO2 in year of projection** (ppm, see Section 3.3)

Notes

- *Each file contains projections data for six climate variables based on the CF methodology (see Section 4).*
- *The projections data are synthetic and do not represent a forecast.*
- *The projections data have been developed for use as input to agricultural simulation models.*
- *In the projections data, the intensity of the rain on rain days is perturbed, but the sequence of rain/no-rain days remains unchanged from the source historical data. Days without rain in the historical time series are projected to days without rain.*
- *The SILO climate database http://www.longpaddock.qld.gov.au/silo can be used to assist in the selection and identification of climate stations.*

- *SILO daily climate are checked for quality and are constantly updated (at least twice a year), hence changes to some data may occur. Any changes in the SILO base-line climate data will affect the projected 2030 and 2050 data.*
- *The same disclaimers that apply to SILO historical data apply to the projections data.*
- *The daily dates, presented in the CF projections files, are the dates from which the 2030 or 2050 projections data are drawn from (using 'change factor' methodology). These dates are essentially an ensemble of individual 2030 or 2050 years. For example, if 19600101 were to be used to represent the first instance of 20300101, then 19610101 would represent the second instance of 20300101 and 20100101would represent the 51st instance of 20300101. The use of historical dates creates the practical advantage of being able to run an analysis in a single pass using a single climate data input file.*
- *In the CF data, at least 51 instances of data are available, if using source data from 1960-2010. Source data prior to 1960 are less useful due to issues related to low climate station density and uncorrected climate trends.*
- *The date-formatting in the APSIM and p51 files differs, as follows:*
  APSIM YYYY DayNumber(1-365/6)
  p51 YYYYMMDD

Examples of information presented in CF climate projections data files are presented in Figures 2.3 and 2.4. Figure 2.3 is a screenshot of projections data for 2050, based on output from the HADCM3 GCM forced by the A1FI emissions scenario with high climate warming sensitivity, formatted for use in **APSIM**. Figure 2.3 provides an example of information presented in a climate projections data file in the '**p51**' format suitable for use in the GRASP pasture model.

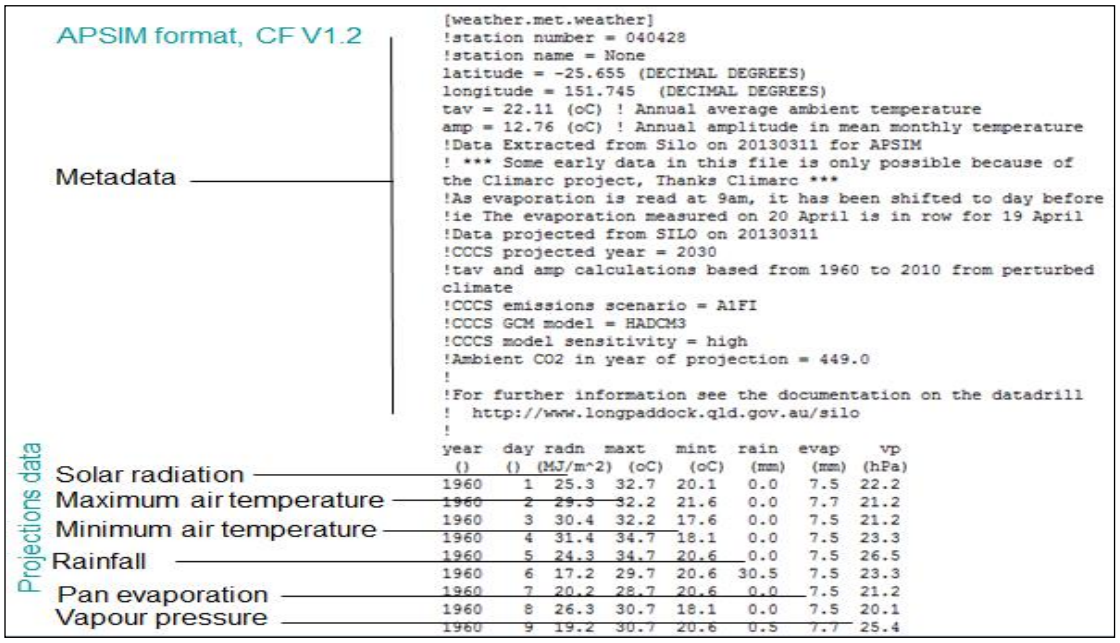

APSIM format, CF V1.2
Metadata
Projections data
Solar radiation
Maximum air temperature
Minimum air temperature
Rainfall
Pan evaporation
Vapour pressure
[weather.met.weather]
!station number = 040428
!station name = None
latitude = -25.655 (DECIMAL DEGREES)
longitude = 151.745 (DECIMAL DEGREES)
tav = 22.11 (oC) ! Annual average ambient temperature
amp = 12.76 (oC) ! Annual amplitude in mean monthly temperature
!Data Extracted from Silo on 20130311 for APSIM
! *** Some early data in this file is only possible because of the Climarc project, Thanks Climarc ***
!As evaporation is read at 9am, it has been shifted to day before
!ie The evaporation measured on 20 April is in row for 19 April
!Data projected from SILO on 20130311
!CCCS projected year = 2030
!tav and amp calculations based from 1960 to 2010 from perturbed climate
!CCCS emissions scenario = A1FI
!CCCS GCM model = HADCM3
!CCCS model sensitivity = high
!Ambient CO2 in year of projection = 449.0
!
!For further information see the documentation on the datadrill
! http://www.longpaddock.qld.gov.au/silo
!
year day radn maxt mint rain evap vp
() () (MJ/m^2) (oC) (oC) (mm) (mm) (hPa)
1960 1 25.3 32.7 20.1 0.0 7.5 22.2
1960 2 29.3 32.2 21.6 0.0 7.7 21.2
1960 3 30.4 32.2 17.6 0.0 7.5 21.2
1960 4 31.4 34.7 18.1 0.0 7.5 23.3
1960 5 24.3 34.7 20.6 0.0 7.5 26.5
1960 6 17.2 29.7 20.6 30.5 7.5 23.3
1960 7 20.2 28.7 20.6 0.0 7.5 21.2
1960 8 26.3 30.7 18.1 0.0 7.5 20.1
1960 9 19.2 30.7 20.6 0.5 7.7 25.4

Figure 2.3 A snapshot of information (projections for 2030) presented in a climate projections data file, suitable for use in APSIM (filename 040428_A1FI_2030_H_HADCM3_-25.6550_151.7450_V1.2.met).

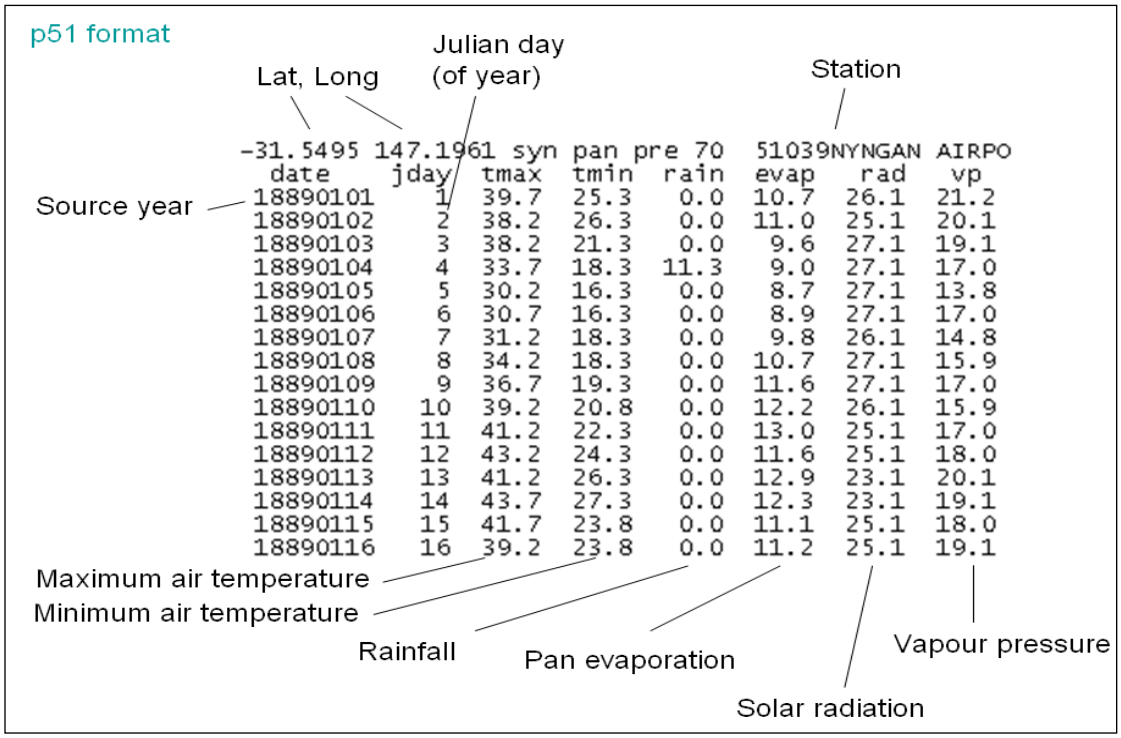


Figure 2.4 A snapshot of information (projections for 2030) presented in a climate projections data file, suitable for use in GRASP (filename 051039_A1FI_2030_M_CSIRO-MK35_-31.5495_147.1961_V1.2.p51).

2.2 'Quantile-matched' (QM) data

Availability of QM 2030 projections data

For 'Quantile-Matched' (QM) 2030 data, users have a choice of 19 GCMs, eight emissions scenarios and three climate warming sensitivities. Each QM 2030 projections file contains projections data for six climate variables using the QM 2030 methodology (see Section 5.1). QM 2030 projections data can be requested for any weather station in Australia. However, drilled data (derived from interpolated surfaces) are not currently available.

QM 2030 based projections data can be ordered through the Long Paddock website's Climate Change Projections web portal:

http://www.longpaddock.qld.gov.au/climateprojections/.

Users are notified by email once an order, for QM 2030 data, has been processed and is ready for download (refer to page 6). The files are contained in a ZIP format archive.

QM 2030 ZIP archives – containing daily projections

QM climate projections data files (as well as a set of historical baseline climate data files, monthly multiplier files, CO2 matching files) for each selected climate site are contained in a ZIP format archive named as follows:

User.name_JobNumber_FileLabel_Archivetype

e.g. john.smith_its138_FileLabel_zip.exe

- Username (derived from your email address)
- JobNumber (i.e. its138, its139, its140, etc.)
- FileLabel (1-8 character label, specified by the user, i.e. qm2030, qmdata, etc.)
- Archivetype (i.e. .zip.exe *for Windows* or .zip *for Unix/Linux*)

File types packaged in the QM ZIP archive containing daily projections (including filename examples) for each selected climate site are:

- **QM projections (for 2030)**
  - 051039_A1F1_2030_M_CSIRO-MK35_-31.5495_147.1961_QMv3.0.met (described in this Section)
- **Historical baseline climate data**
  - 051039_SILO_-31.5495_147.1961_QMv3.0.met (described in Section 2.3)
- **Multiplier files**
  - 051039_-31.5495_147.1961_V1.2.multiplier (described in Section 3.1)
- **CO2 matching files**
  - 051039_-31.5495_147.1961_NamesList.txt (described in Section 3.2)

QM 2030 ZIP archives - containing diagnostic plots

QM 2030 diagnostic plots (which include comparison of model projections plots for 2030 based on the A1B emissions scenario, historical time series plots, QM histograms plots and quantile trend plots) for each selected climate site are contained in a ZIP format archive as follows:

User.name_JobNumber_FileLabel_Plots_Archivetype

e.g. john.smith_its138_plots_zip.exe

- Username (derived from your email address)
- JobNumber (i.e. its138, its139, its140, etc.)
- FileLabel (1-8 character label, specified by the user, i.e. qm2030, testdata, etc.)
- Plots (shows that plot files are included)
- Archivetype (i.e. .zip.exe *for Windows* or .zip *for Unix/Linux*)

File types packaged in QM 2030 ZIP archives containing diagnostics plots (including filename examples) are:

- **Comparison of model projections plots**
  - 051039_A1B_M_2030_31.5495_147.1961_mdlperf_V1.2.png (described in Section 3.7)
- **Historical time series plots**
  - 051039_-31.5495_147.1961_V1.2.png (described in Section 3.5)
- **Quantile trend plots (files for 5 climate variables) ***
  - RadnPropOfEtlogit_051039_[10,50,90]_1957_2010_2030_QuantileTrends_051039.png
  - RainCubeRoot_051039_[10,50,90]_1957_2010_2030_QuantileTrends_051039.png
  - SH_051039_[10,50,90]_1957_2010_2030_QuantileTrends_051039.png
  - T.Max_051039_[10,50,90]_1957_2010_2030_QuantileTrends_051039.png
  - T.Min_051039_[10,50,90]_1957_2010_2030_QuantileTrends_051039.png
    (described in Section 3.9)
- **Histograms of QM projections (files for 6 climate variables) ***
  - RadnPropOfEtlogit_051039_[10,50,90]_1957_2010_2030_Histograms_051039_HADCM3_A1FI_high.png
  - Rain_051039_[10,50,90]_1957_2010_2030_Histograms_051039_HADCM3_A1FI_high.png
  - RainCubeRoot_051039_[10,50,90]_1957_2010_2030_Histograms_051039_HADCM3_A1FI_high.png
  - VP_051039_[10,50,90]_1957_2010_2030_Histograms_051039_HADCM3_A1FI_high.png
  - T.Max_051039_[10,50,90]_1957_2010_2030_Histograms_051039_HADCM3_A1FI_high.png
  - T.Min_051039_[10,50,90]_1957_2010_2030_Histograms_051039_HADCM3_A1FI_high.png
    (described in Section 3.10)

* File naming syntax for Quantile trend and Histogram plots supersedes that presented in earlier User Guides.

QM 2030 Projections files

Once a ZIP archive is opened, individual QM 2030 climate projections data files and ancillary files are then accessible. The QM 2030 climate projections data files are named as follows:

LocationCode_Scenario_ProjectionsYear_ClimateWarming sensitivity_ModelName_Latitude_Longitude_VersionNumber.SILOformat

e.g. 051039_A1FI_2030_M_CSIRO-MK35_-31.5495_147.1961_QMv3.0.met

- 'LocationCode' is a six digit number (BoM station code if patched-point, i.e. 051039, *or all zeros if drilled (from interpolated surfaces), i.e. 000000*)
- Scenario (emissions scenario, i.e. A1B, A1FI, etc.)
- Projections year (2030)
- Climate warming sensitivity (rate of global warming, i.e. L, M, H)
  - 'L', 'M' and 'H' refer to the 10th, 50th and 90th percentile values respectively.
- Model Name (i.e. CSIRO-MK35, HADGEM1, HI, HP, etc.)
- Latitude and longitude of the station or location in decimal degrees
- Version Number (where QMv2.2 or QMv3.0 represents QM data)
- SILO format (either 'met' for APSIM or 'p51' for GRASP)

Data contained in the QM 2030 projections data files are formatted the same as those in the CF projections data files (Figures 2.3 and 2.4). However, metadata provided in QM projections data files includes an additional column containing reference codes for QM synthesis methods.

Notes *(where different from caveats in Section 2.1 associated with the CF data)*

- *The QM projections use a 1957-2010 training period to compute the perturbation rules that are applied to that historical baseline. The tav (annual average ambient temperature) and amp (annual amplitude in mean monthly temperature) parameters shown in the QM metadata in the APSIM files are calculated based on the 1957-2010 training period.*
- *The daily dates, presented in the QM projections files, indicate only the historical date that was the source of the associated perturbed data before the QM methodology was applied. The month day and Julian day fields in the projection files are correct.*
- *QMv3.0 represents a code upgrade from QMv2.2 (see section 11.10).*

Availability of QM 2050 Projections files

Due to a lack of raw daily GCM data, QM 2050 projections data are only available for a single GCM (ECHAM5), the A1B emissions scenario and median climate warming sensitivity. Each QM 2050 file contains projections data for rainfall, maximum and minimum temperature projections are based on the QM 2050 methodology (see Section 5.2), while and vapour pressure, evaporation and solar radiation projections are based on the QM 2030 methodology(see Section 5.1).

Since July 1, 2012, QM 2050 projections data have been limited to a test-set of 52 locations within Australia (Figure 2.5).

A file, **testSites.csv**, lists those locations, including station names, location codes, latitudes and longitudes. Access to more locations is expected, via the Climate Change Projections web portal, at some stage in the future.

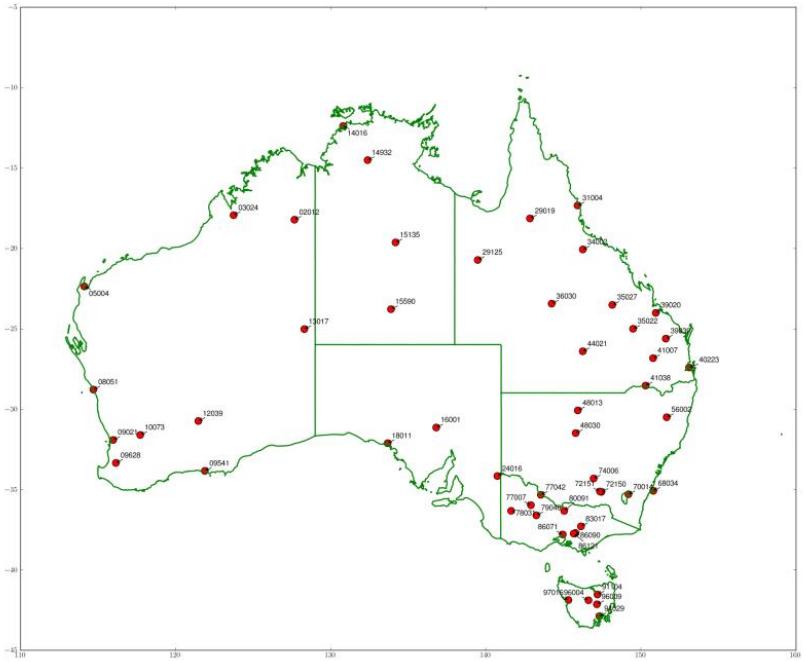


Figure 2.5 Map showing 52 locations for which ‘quantile-matched’ projections data for 2050 are available.

The QM 2050 station location file and QM 2050 projections data can be downloaded via **ftp://climate.mft.derm.qld.gov.au/Climate_Scenarios/QM_2050_TestData/**.

QM 2050 ZIP archives

QM 2050 climate projections data and diagnostic files for each climate site are contained in self-extracting ZIP format archives at **ftp://climate.mft.derm.qld.gov.au/Climate_Scenarios/QM_2050_TestData/**

as follows:

LocationCode_ProjectionsMethod_ProjectionsYear_DEMO.Archivetype

e.g. 002012_QM_2050_DEMO.zip.exe

- 'LocationCode' is a 6 digit number (BoM station code if patched-point, i.e. 051039, *or all zeros if drilled (from interpolated surfaces), i.e. 000000*)
- ProjectionsMethod (QM, represents 'quantile-matched' projections)
- ProjectionsYear (2050)
- DEMO (represents QMV2.2.10 2050 test dataset)
- Archivetype (.zip.exe *for Windows*)

QM 2050 Projections files

Once a ZIP archive is opened, individual QM 2050 climate projections data files and ancillary files are then accessible. The QM 2050 climate projections data files are named as follows:

LocationCode_ProjectionsYear_ProjectionsMethod_VersionNumber.SILOformat

e.g. 002012_2050_QM2.2.met

- 'LocationCode' is a six digit number (BoM station code if patched-point, i.e. 051039, *or all zeros if drilled, i.e. 000000*)
- Projections year (2050)
- Version Number (where QM2.2 represents QM 2050 test data)
- SILO format (either 'met' for APSIM or 'p51' for GRASP)

Data contained in the QM 2050 projections data files are formatted the same as those in the QM projections data files.

***Note** (applies in addition to caveats associated with the QM 2030 data)*

- *The QM projections data for 2050 are available for a single GCM (ECHAM5) one, emissions scenario (A1B) and one climate warming sensitivity (median). Each file contains projections data for six climate variables (rainfall, maximum and minimum temperature projections are based on the QM 2050 methodology (see Section 5) and vapour pressure, evaporation and solar radiation projections are based on the QM 2030 methodology). ECHAM5 is unique, in that it is the only GCM that has both a high rank (as assessed by the Expert Review Panel) and a complete set of raw GCM daily data from 1900 to 2100.*

2.3 Historical baseline climate data files

Along with projections data, the ZIP archive also contains files of historical climate data for baseline comparison. The historical data have been extracted from the SILO database.

The SILO historical database, as it currently exists, is relied upon by the scientific community across Australia and provides researchers and modellers with seamless spatially and temporally complete Australia-wide daily climate data from 1889 to current. CCS historical baseline climate datasets are available from 1960 onwards, since this is the period of highest quality data. SILO grew from a need for climate data in various formats suitable for systems modelling. The SILO datasets are based on historical data provided by the Bureau of Meteorology (BoM), which DSITI has enhanced by error checking, interpolating across Australia on a 5km grid, and on this basis, ‘ infilling’ missing data at each station.

Both CF and QM historical data files are named as follows:

LocationCode_SILO_Latitude_Longitude_VersionNumber.SILOformat

e.g. 056002_SILO_-30.5167_151.6681_V1.2.met

- LocationCode is a six digit number (BoM station code if patched-point, i.e. 051039, *or all zeros if drilled (from interpolated surfaces), i.e. 000000*)
- Obs (indicates observed/historical data)
- SILO (indicates SILO baseline data)
- Latitude (of your station in decimal degrees)
- Longitude (as above)
- Version Number (i.e. V1.2 as used in CF data, QMv2.2 or QMv3.0 as used in QM data)
- SILO_format (either ‘met’ for APSIM or ‘p51’ for GRASP)

Note the different date formats in the APSIM and p51 files:

- APSIM YYYY DayNumber(1-365/6)
- p51 YYYYMMDD

An example of information presented in an historical baseline climate data file is presented in Figure 2.6. This format is suitable for use in APSIM.

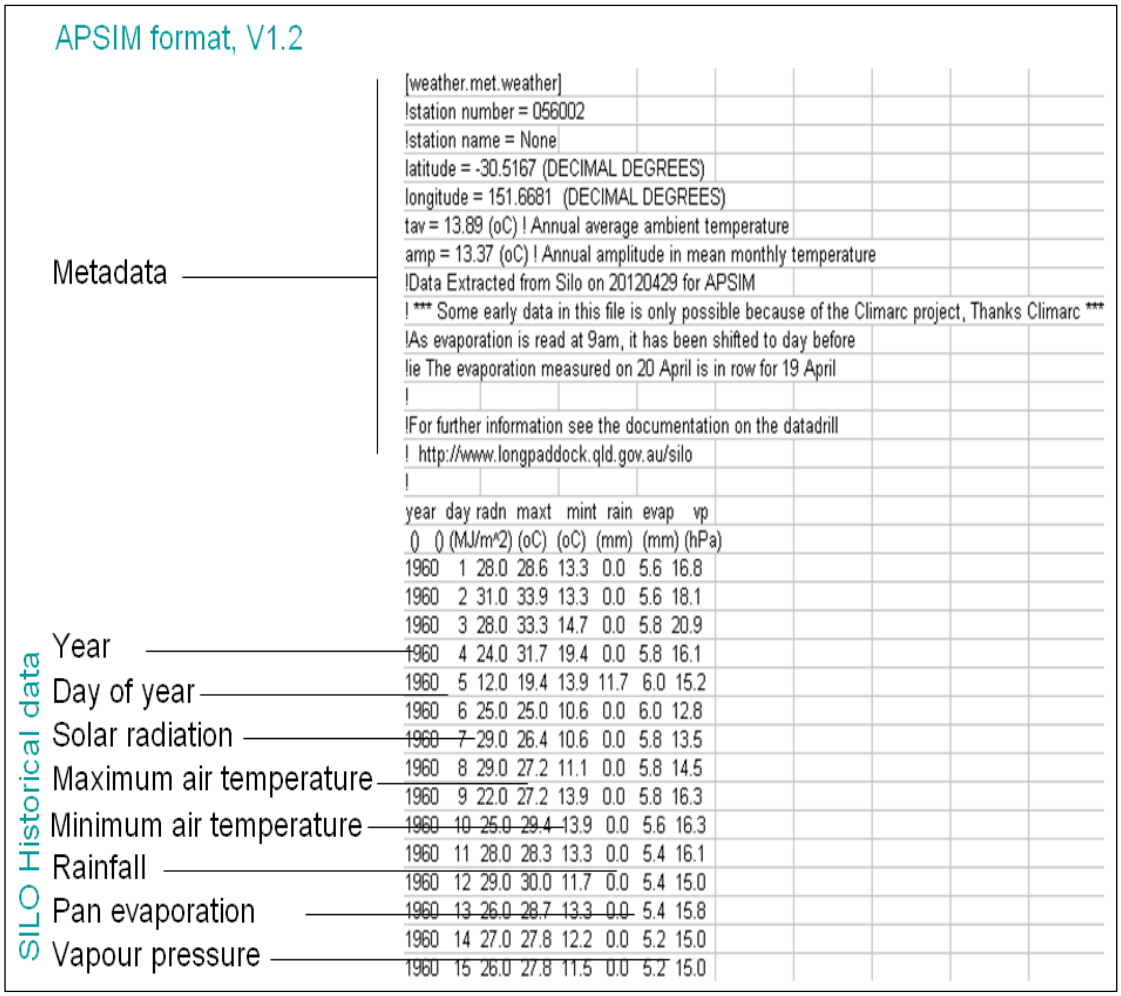

APSIM format, V1.2
SILO Historical data
Metadata
Year
Day of year
Solar radiation
Maximum air temperature
Minimum air temperature
Rainfall
Pan evaporation
Vapour pressure
[weather.met.weather]
!station number = 056002
!station name = None
latitude = -30.5167 (DECIMAL DEGREES)
longitude = 151.6681 (DECIMAL DEGREES)
tav = 13.89 (oC) ! Annual average ambient temperature
amp = 13.37 (oC) ! Annual amplitude in mean monthly temperature
!Data Extracted from Silo on 20120429 for APSIM
! *** Some early data in this file is only possible because of the Climarc project, Thanks Climarc ***
!As evaporation is read at 9am, it has been shifted to day before
!ie The evaporation measured on 20 April is in row for 19 April
!
!For further information see the documentation on the datadrill
! http://www.longpaddock.qld.gov.au/silo
!
year day radn maxt mint rain evap vp
() () (MJ/m^2) (oC) (oC) (mm) (mm) (hPa)
1960 1 28.0 28.6 13.3 0.0 5.6 16.8
1960 2 31.0 33.9 13.3 0.0 5.6 18.1
1960 3 28.0 33.3 14.7 0.0 5.8 20.9
1960 4 24.0 31.7 19.4 0.0 5.8 16.1
1960 5 12.0 19.4 13.9 11.7 6.0 15.2
1960 6 25.0 25.0 10.6 0.0 6.0 12.8
1960 7 29.0 26.4 10.6 0.0 5.8 13.5
1960 8 29.0 27.2 11.1 0.0 5.8 14.5
1960 9 22.0 27.2 13.9 0.0 5.8 16.3
1960 10 25.0 29.4 13.9 0.0 5.6 16.3
1960 11 28.0 28.3 13.3 0.0 5.4 16.1
1960 12 29.0 30.0 11.7 0.0 5.4 15.0
1960 13 26.0 28.7 13.3 0.0 5.4 15.8
1960 14 27.0 27.8 12.2 0.0 5.2 15.0
1960 15 26.0 27.8 11.5 0.0 5.2 15.0

Figure 2.6 A snapshot of information (observed data) presented in a historical-baseline climate data file suitable for use in APSIM (filename 056002_SILO_-30.5167_151.6681_V1.2.met).

Notes

- *The metadata at the start of each APSIM format SILO historical data file include station details (location code, name, latitude, longitude), baseline climate statistics (annual average ambient temperature and annual amplitude in mean monthly temperature).*
- *In the QM historical data files, an additional 'code' column contains 6 digits outlining codes used to distinguish between actual observations or interpolated data.*
- *When ordering CF 2030 or CF 2050 projections data, users can select historical baseline climate data for years from 1960 onwards. The default period for calculating the long term climate statistics ('tav' and 'amp') is currently 1960 to 2010,'climate-changed'. However, if 1970 to 2000 is selected, calculations will be based on that specific period, 'climate-changed'.*
- *In the QM historical data files, the default period for both the historical baseline climate data and calculated 'tav' and 'amp' is 1957 to 2010, 'climate-changed'. For QM, the default 1957 to 2010 period can't be changed.*

2.4 An end-user example

A typical sequence for an end user is provided by the following example.

An end-user is interested in studying the impacts on grape vines near Mildura due to a change in the frequency of hot days (days where the maximum temperature exceeds 35^{o}C). They would like to know what change could be expected around the year 2030 assuming a worst case emissions scenario (A1FI) and high climate sensitivity to global warming. However, they are only interested in the projections from a few (five) GCMs which are recommended as being relatively good performers. They would also like to compare the differences based on the 'change factor' (CF) and 'quantile-matched' (QM) methods.

The end-user will first need to place a data order, based on the above-mentioned variables, via the Long Paddock website's Climate Change Projections web portal **http://www.longpaddock.qld.gov.au/climateprojections/**. Once the projections data have been processed, the end-user will receive an email containing an ftp link for collection of the data. In most cases, ZIP archives containing the data will be ready for collection within 2 hours (may take longer for large orders). When projections data, without diagnostics are requested, there will be one ZIP archive per order. In this example, there would be two sets of ZIP archives (one for CF data and one for QM data).

If the user were to open either the CF or QM ZIP archive, the user will have access to many files. For example, in the CF ZIP archive, the CF projections data files refer to the GCMs, emissions scenarios, target years, climate sensitivity values, and output formats that were selected during the order process. In this case, the user will have received for each of the five GCMs, just those files corresponding to the specified location, year 2030, A1FI emissions scenario and high climate sensitivity. That equates to a total of five CF projections data files (one for each GCM). For each location requested, the ZIP archives contain a range of additional files. In the ZIP archives, these additional files include the corresponding observed data as contained in the SILO data base (see Section 2.3), CO_2 matching files, log warning files, monthly multiplier files, historical time-series plots and comparison of model projections plots (see Section 3).

As at January 20, 2015, by default the years in the SILO observed daily data file and the CF projected daily data file, are dated from January 1, 1960 to December 31, 2010. However, if desired, the end-user can select a shorter or longer period when making their web-based order (the latest end year can be 2013). For example, in calculating the frequency of hot days, the end-user can select a window of years (e.g. 1971 to 2000) from the observations, and compare the results with the same window (1971 to 2000) from the 2030 projections data files. The selected historical baseline for the QM data is fixed, from January 1, 1957 to December 31, 2010.

The data from each file can be imported directly into a spread sheet or other program and the user can focus, in this case, on just the daily temperatures. It is recommended that the end-user perform some basic calculations and plots of the data and then refer to the corresponding ancillary files that are contained in each archive. This can provide a check that the correct data has been accessed for the

specific purpose. In some cases the ancillary files may contain the exact information that the end-user is interested in.

3 Files with additional information

Many ancillary files are supplied in the ZIP archives to supplement the climate projections data. The information contained in these ancillary files can be used independently from the 2030/50 projections data files.

'Change factor' (CF) based ancillary files include:

- multiplier files
- CO2 matching files
- log warning files
- historical time series plots
- comparison of model projections plots.

Additional to these, 'quantile-matched' (QM) based ancillary files include:

- monthly quantile trend plots
- histograms of projected frequency distributions.

In addition, the following ancillary files (not available via the CCS web portal) can be made available, if requested:

- an historical and projected CO2 concentrations file
- CF based frequency distribution plots
- plots of simulated 20th and 21st Century climate according to available GCM runs
- a single-station CF based transient climate data test set for 1889-2100.

3.1 Multiplier files

The data, or 'multipliers', contained in these files include:

- projected amounts of global warming for each emissions scenario at 2030 and 2050
- projected rates of change per degree of 21st Century global warming for a range of climate variables for each GCM.

The multipliers are listed for each of the 19 GCMs (Section 8, Table 8.2), four GCM composites based on the Representative Future Climate partitions (WP, WI, HP and HI) described in Section 8 (Table 8.3), eight emissions scenarios (Table 7.1) and three climate sensitivities (Table 7.3). These multipliers are the ones that have been used to calculate the climate 'change factors' that have been applied to the SILO historical daily climate data to produce the 2030 and 2050 CF climate projections data. The multiplier files include both monthly and annual values.

The 'change factors' are calculated, for specific climate variables, by multiplying amounts of global warming by rates of change per degree of 21st Century global warming. Further detail, related to the application of the data contained in the

monthly multiplier files, is contained in Section 4 'Change factor' (CF) methodology and Section 7.3 'Climate warming sensitivity'.

The multiplier files are typically named:

LocationCode_Latitude_Longitude_VersionNo.multiplier

e.g. 051039_-31.5495_147.1961_V1.2.multiplier

- LocationCode is a six digit number (BoM station code if patched-point, i.e. 051039, *or all zeros if drilled (from interpolated surfaces), i.e. 000000*)
- Latitude (of the station or location in decimal degrees)
- Longitude (as above)
- VersionNumber (V1.2 represents CF data)
- Multiplier (this is a notepad file)

Variables contained in the CF V1.2 multiplier files are:

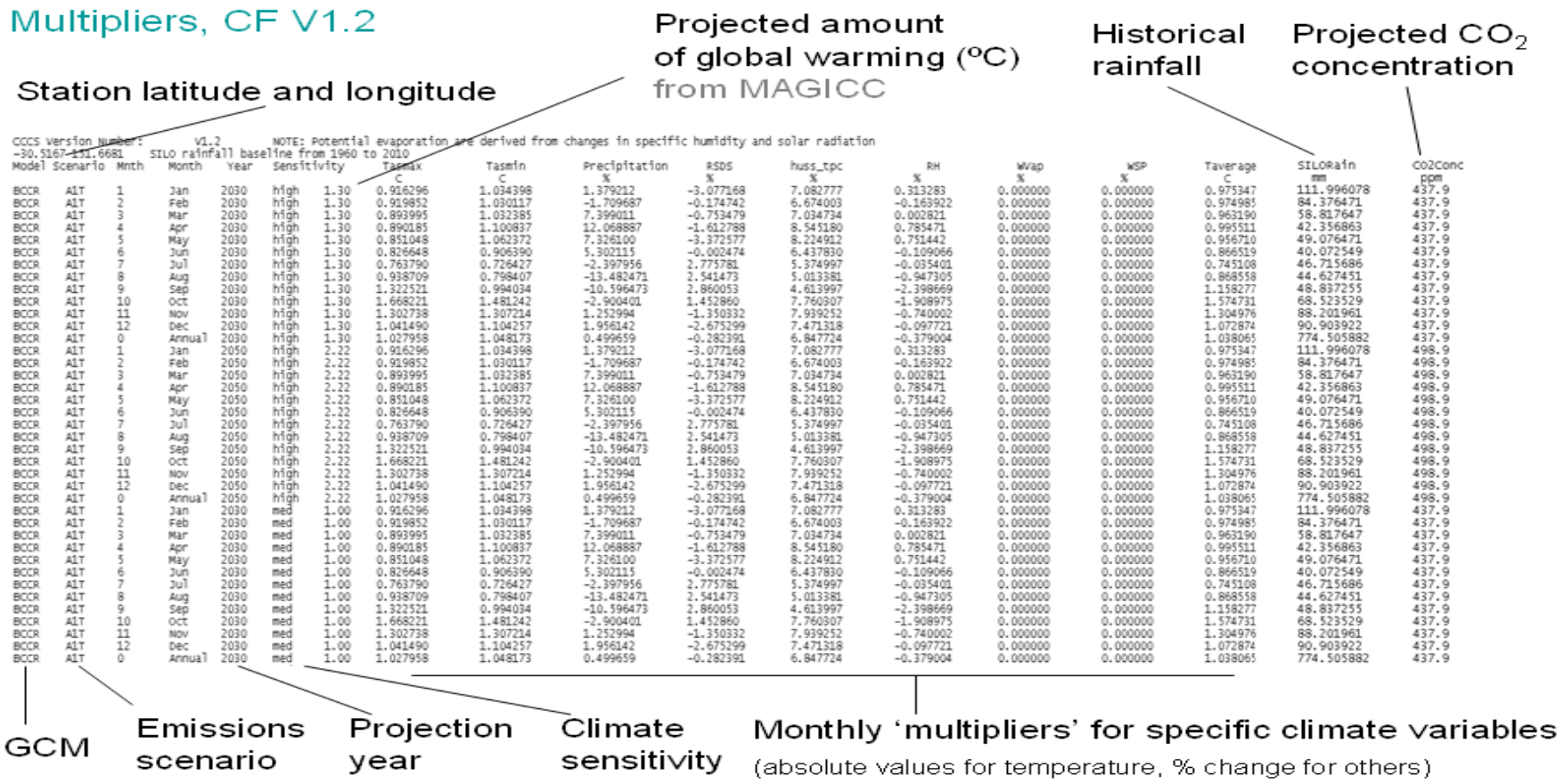
- Column 1: Model: Model name (for each of the 19 GCMs listed in Table 8.2 and four GCM composites based on the Representative Future Climate partitions (WP, WI, HP and HI) listed in Table 8.3).
- Column 2: Scenario: Emissions scenario (A1FI, A1B, A1T, A2, B1, B2, CO2_450 and CO2_550)
- Column 3: Mnth: Month (numeric 1-12, 13)
- Column 4: Month: Month (alpha-numeric Jan to Dec, Annual)
- Column 5: Year: Projections year (2030 and 2050)
- Column 6 and 7: Sensitivity: Climate warming sensitivity ('low, median, high') refers to the 10^{th}, 50^{th} and 90^{th} percentile values respectively and a value indicating the projected amount of global warming (ºC) at 2030 or 2050.

Column 8 to 18: Projected change per degree of 21^{st} Century global warming for:

- Tasmax and Tasmin: Maximum and minimum temperature (absolute change, ºC)
- Precipitation: Rainfall (per cent change)
- RSDS: Solar radiation (per cent change)
- huss_tpc: Specific humidity (per cent change)
- RH: Relative humidity (per cent change) if available
- WVap: Water vapour (per cent change), 0 if not available
- WSP: Wind speed (per cent change), o if not available
- Taverage: Mean temperature (absolute change, ºC)
- SILORain: SILO rainfall (observed mean for the selected baseline period, mm)
- CO2Conc: Projected CO_2 concentration (ppm).

Values listed in the SILORain column are not projections, but are the observed means for the historical climate baseline, as selected by the user (which is displayed in the second line of the data file). In some cases 'nan' may be displayed where a numerical value has been expected, indicating that the computed values were out of range.

An example of information presented in a CF V1.2 multiplier file is presented in Figure 3.1.



CCCS Version Number: V1.2 NOTE: Potential evaporation are derived from changes in specific humidity and solar radiation

-30.5167 151.6681 SILO rainfall baseline from 1960 to 2010

Model	Scenario	Mnth	Month	Year	Sensitivity		Tasmax	Tasmin	Precipitation	RSDS	huss_tpc	RH	WVap	WSP	Taverage	SILORain	CO2Conc
							C	C	%	%	%	%	%	%	C	mm	ppm
BCCR	ALT	1	Jan	2030	high	1.30	0.916296	1.034398	1.379212	-3.077168	7.082777	0.313283	0.000000	0.000000	0.975347	111.996078	437.9
BCCR	ALT	2	Feb	2030	high	1.30	0.919852	1.030117	-1.709687	-0.174742	6.674003	-0.163922	0.000000	0.000000	0.974985	84.376471	437.9
BCCR	ALT	3	Mar	2030	high	1.30	0.893995	1.032385	7.399011	-0.753479	7.034734	0.002821	0.000000	0.000000	0.963190	58.817647	437.9
BCCR	ALT	4	Apr	2030	high	1.30	0.890185	1.100837	12.068887	-1.612788	8.545180	0.785471	0.000000	0.000000	0.995511	42.356863	437.9
BCCR	ALT	5	May	2030	high	1.30	0.851048	1.062372	7.326100	-3.372577	8.224912	0.751442	0.000000	0.000000	0.956710	49.076471	437.9
BCCR	ALT	6	Jun	2030	high	1.30	0.826648	0.906390	5.302115	-0.002474	6.437830	-0.109066	0.000000	0.000000	0.866519	40.072549	437.9
BCCR	ALT	7	Jul	2030	high	1.30	0.763790	0.726427	-2.397956	2.775781	5.374997	-0.035401	0.000000	0.000000	0.745108	46.715686	437.9
BCCR	ALT	8	Aug	2030	high	1.30	0.938709	0.798407	-13.482471	2.541473	5.013381	-0.947305	0.000000	0.000000	0.868558	44.627451	437.9
BCCR	ALT	9	Sep	2030	high	1.30	1.322521	0.994034	-10.596473	2.860053	4.613997	-2.398669	0.000000	0.000000	1.158277	48.837255	437.9
BCCR	ALT	10	Oct	2030	high	1.30	1.668221	1.481242	-2.900401	1.452860	7.760307	-1.908975	0.000000	0.000000	1.574731	68.523529	437.9
BCCR	ALT	11	Nov	2030	high	1.30	1.302738	1.307214	1.252994	-1.350332	7.939252	-0.740002	0.000000	0.000000	1.304976	88.201961	437.9
BCCR	ALT	12	Dec	2030	high	1.30	1.041490	1.104257	1.956142	-2.675299	7.471318	-0.097721	0.000000	0.000000	1.072874	90.903922	437.9
BCCR	ALT	0	Annual	2030	high	1.30	1.027958	1.048173	0.499659	-0.282391	6.847724	-0.379004	0.000000	0.000000	1.038065	774.505882	437.9
BCCR	ALT	1	Jan	2050	high	2.22	0.916296	1.034398	1.379212	-3.077168	7.082777	0.313283	0.000000	0.000000	0.975347	111.996078	498.9
BCCR	ALT	2	Feb	2050	high	2.22	0.919852	1.030117	-1.709687	-0.174742	6.674003	-0.163922	0.000000	0.000000	0.974985	84.376471	498.9
BCCR	ALT	3	Mar	2050	high	2.22	0.893995	1.032385	7.399011	-0.753479	7.034734	0.002821	0.000000	0.000000	0.963190	58.817647	498.9
BCCR	ALT	4	Apr	2050	high	2.22	0.890185	1.100837	12.068887	-1.612788	8.545180	0.785471	0.000000	0.000000	0.995511	42.356863	498.9
BCCR	ALT	5	May	2050	high	2.22	0.851048	1.062372	7.326100	-3.372577	8.224912	0.751442	0.000000	0.000000	0.956710	49.076471	498.9
BCCR	ALT	6	Jun	2050	high	2.22	0.826648	0.906390	5.302115	-0.002474	6.437830	-0.109066	0.000000	0.000000	0.866519	40.072549	498.9
BCCR	ALT	7	Jul	2050	high	2.22	0.763790	0.726427	-2.397956	2.775781	5.374997	-0.035401	0.000000	0.000000	0.745108	46.715686	498.9
BCCR	ALT	8	Aug	2050	high	2.22	0.938709	0.798407	-13.482471	2.541473	5.013381	-0.947305	0.000000	0.000000	0.868558	44.627451	498.9
BCCR	ALT	9	Sep	2050	high	2.22	1.322521	0.994034	-10.596473	2.860053	4.613997	-2.398669	0.000000	0.000000	1.158277	48.837255	498.9
BCCR	ALT	10	Oct	2050	high	2.22	1.668221	1.481242	-2.900401	1.452860	7.760307	-1.908975	0.000000	0.000000	1.574731	68.523529	498.9
BCCR	ALT	11	Nov	2050	high	2.22	1.302738	1.307214	1.252994	-1.350332	7.939252	-0.740002	0.000000	0.000000	1.304976	88.201961	498.9
BCCR	ALT	12	Dec	2050	high	2.22	1.041490	1.104257	1.956142	-2.675299	7.471318	-0.097721	0.000000	0.000000	1.072874	90.903922	498.9
BCCR	ALT	0	Annual	2050	high	2.22	1.027958	1.048173	0.499659	-0.282391	6.847724	-0.379004	0.000000	0.000000	1.038065	774.505882	498.9
BCCR	ALT	1	Jan	2030	med	1.00	0.916296	1.034398	1.379212	-3.077168	7.082777	0.313283	0.000000	0.000000	0.975347	111.996078	437.9
BCCR	ALT	2	Feb	2030	med	1.00	0.919852	1.030117	-1.709687	-0.174742	6.674003	-0.163922	0.000000	0.000000	0.974985	84.376471	437.9
BCCR	ALT	3	Mar	2030	med	1.00	0.893995	1.032385	7.399011	-0.753479	7.034734	0.002821	0.000000	0.000000	0.963190	58.817647	437.9
BCCR	ALT	4	Apr	2030	med	1.00	0.890185	1.100837	12.068887	-1.612788	8.545180	0.785471	0.000000	0.000000	0.995511	42.356863	437.9
BCCR	ALT	5	May	2030	med	1.00	0.851048	1.062372	7.326100	-3.372577	8.224912	0.751442	0.000000	0.000000	0.956710	49.076471	437.9
BCCR	ALT	6	Jun	2030	med	1.00	0.826648	0.906390	5.302115	-0.002474	6.437830	-0.109066	0.000000	0.000000	0.866519	40.072549	437.9
BCCR	ALT	7	Jul	2030	med	1.00	0.763790	0.726427	-2.397956	2.775781	5.374997	-0.035401	0.000000	0.000000	0.745108	46.715686	437.9
BCCR	ALT	8	Aug	2030	med	1.00	0.938709	0.798407	-13.482471	2.541473	5.013381	-0.947305	0.000000	0.000000	0.868558	44.627451	437.9
BCCR	ALT	9	Sep	2030	med	1.00	1.322521	0.994034	-10.596473	2.860053	4.613997	-2.398669	0.000000	0.000000	1.158277	48.837255	437.9
BCCR	ALT	10	Oct	2030	med	1.00	1.668221	1.481242	-2.900401	1.452860	7.760307	-1.908975	0.000000	0.000000	1.574731	68.523529	437.9
BCCR	ALT	11	Nov	2030	med	1.00	1.302738	1.307214	1.252994	-1.350332	7.939252	-0.740002	0.000000	0.000000	1.304976	88.201961	437.9
BCCR	ALT	12	Dec	2030	med	1.00	1.041490	1.104257	1.956142	-2.675299	7.471318	-0.097721	0.000000	0.000000	1.072874	90.903922	437.9
BCCR	ALT	0	Annual	2030	med	1.00	1.027958	1.048173	0.499659	-0.282391	6.847724	-0.379004	0.000000	0.000000	1.038065	774.505882	437.9

Figure 3.1 A snapshot of information contained in a CF V1.2 multiplier file. For the selected location multipliers include, for each climate variable, the projected change per degree of 21st Century global warming and projected amount of global warming at 2030 and 2050 used to construct CF daily climate projections data (filename 056002_30.5167_151.6681_V1.2.multiplier). Multipliers are listed for 19 individual GCMs and the four GCM composites (WP, WI, HP and HI) based on Representative Future Climate partitions. Other information (historical rainfall and projected CO_2 concentration) are also included.

3.2 CO_2 matching files

CF Version 1.2 data includes look-up tables called 'CO_2 matching files' that have been provided for each location. These files list the CO_2 concentrations associated with each projections file that has been provided.

The CO_2 matching files are named as follows:

LocationCode_Latitude_Longitude_NamesList.txt

e.g. 051039_-31.5495_147.1961_NamesList.txt

- LocationCode is a six digit number (BoM station code if patched-point, i.e. 051039, or all zeros if drilled (from interpolated surfaces), i.e. 000000)
- Latitude and longitude of the station or location in decimal degrees
- NamesList.txt (CO2 matching file)

An example of information presented in a CO_2 matching file is presented in Figure 3.2, with metadata, as follows:

LocationCode_Scenario_ProjectionsYear_ClimateWarming sensitivity_ModelName_Latitude_Longitude_VersionNumber.SILOformat CO_2

e.g. 051039_A2_2030_L_CSIRO-MK35_-35.5495_147.1961_V1.2.met 444.00

- LocationCode is a six digit number (BoM station code if patched-point, i.e. 051039, *or all zeros if drilled, i.e. 000000*)
- Scenario (listed for each emissions scenario, i.e. A1B, A1FI, etc.)
- Projections year (i.e. 2030 or 2050)
- Climate warming sensitivity (rate of global warming, i.e. L, M, H)
- 'L', 'M' and 'H' refer to the 10^{th}, 50^{th} and 90^{th} percentile values respectively.
- Model Name (listed for each of 19 GCMs and four RFCs, i.e. CSIRO-MK35, HADGEM1, HI, HP, etc.)
- Latitude and longitude of the station or location in decimal degrees
- Version Number (V1.2 represents CF data)
- SILO format (either 'met' for APSIM or 'p51' for GRASP)
- CO_2 (concentration for the listed climate projections year and climate warming sensitivity), to three decimal places.

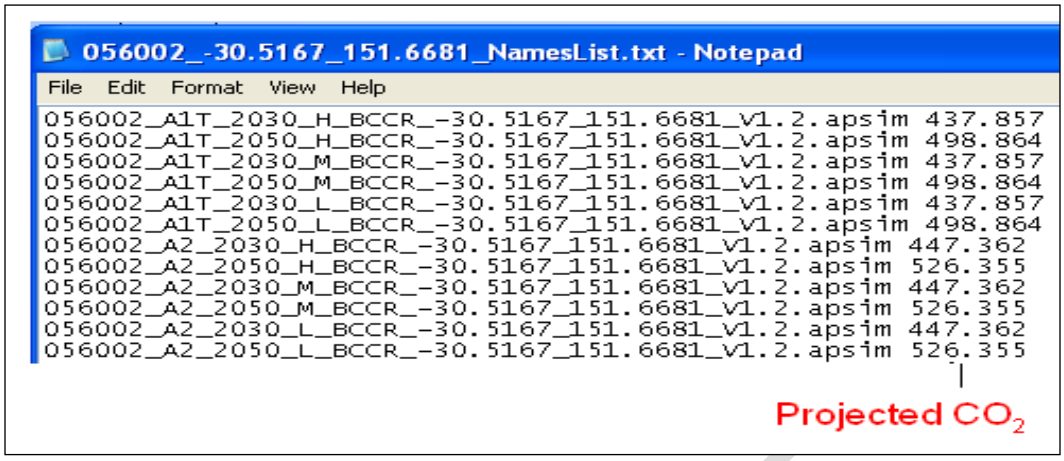


Figure 3.2 A snapshot of information presented in a CO_2 matching file (filename 056002_-30.5167_151.6681_NamesList.txt).

3.3 CO_2 concentrations files

Two CO_2 concentrations files are available. These are:

- an annual file, named ***CO2_concentrations_annual.dat*** containing CO_2 concentrations for each year from 1970 to 2100
- a decadal file, named ***CO2_concentrations_decadal.dat*** containing CO_2 concentrations for each decade from 1970 to 2100.

These files can be downloaded from:

ftp://climate.mft.derm.qld.gov.au/Climate_Scenarios/Documentation

The CO_2 data used in the CCS project, and listed in these CO_2 concentrations files, is sourced from the IPCC . The IPCC has documented a range of emission scenarios featured in the 'Special Report on Emissions Scenarios (SRES)' (IPCC, 2000). Six of the scenarios documented by the IPCC (used in both AR3 and AR4) are utilised in this project, representing outcomes of distinct narratives of economic development, demographic and technological change. The SRES scenarios are: A1FI, A1B, A1T, A2, B1 and B2 (see additional technical details describing these emissions scenarios in Section 7.1).

In addition to the SRES scenarios, the CO_2 concentrations files include two 'stabilisation scenarios' (CO2-450 and CO2-550) based on the work of Wigley *et al*. (1996) and the CCS web portal includes these as options when ordering data. The stabilisation scenarios examine the implications of stabilising CO_2 at 2100 at various concentrations.

The CO_2 concentration files also contain the preliminary IPCC AR3 CO_2 estimates headed with the subscript 'p' and two older scenarios IS92A and IS92A/SAR.

Users should be aware that projected futures CO_2 concentration pathways are uncertain and may 'undershoot' or 'overshoot' the proposed trajectories.

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Furthermore, the CO_2 concentration files also include CO_2 data for four scenarios based on Representative Concentration Pathways (RCP 3-PD, RCP 4.5, RCP6.0 and RCP8.5). These RCPs that have been determined by projected radiative forcing and have been used for the development of information for the IPCC Fifth Assessment Report (AR5). Further documentation about these RCPs is available from:

- the IPCC Expert Meeting Report on New Scenarios (Noordwijkerhout report) http://www.aimes.ucar.edu/docs/IPCC.meetingreport.final.pdf
- the "Representative Concentration Pathways (RCPs) Draft Handshake" http://www.aimes.ucar.edu/docs/RCP_handshake.pdf
- the IPCC website at http://sedac.ciesin.columbia.edu/ddc/ar5_scenario_process/RCPs.html.

The information contained in the decadal CO_2 concentrations file is shown in Figure 3.3 and Figure 3.4.

Notes

- ***Projected 2030 CO_2 concentrations for:***
  - ***A1FI (449ppm) are equivalent to RCP 8.5***
  - ***A1T (435ppm) are equivalent to RCP 4.5***

- ***Projected 2050 CO_2 concentrations for:***
  - ***A1FI (555ppm) slightly exceed RCP 8.5 (541ppm)***

- *Users should note that AR3 and AR4 based CO_2 concentration data is derived from the BERN model. Some GCM models used CO_2 from the ISAM model for their atmospheric forcing. The difference between the ISAM and BERN models for the year 2050 for each SRES scenario is about 10ppm, which is less than the difference between the 'high' and 'low' versions of each model. Since more GCM models use CO_2 derived from the BERN model we supply this estimate with the climate data.*

- *The preliminary IPCC AR3 CO_2 estimates, two older scenarios IS92A and IS92A/SAR and the new RCP CO_2 data are for reference – there are no corresponding CF or QM climate files.*

Decadal CO_2 concentrations (ppm)

#AR4 forcings: atmospheric CO2 concentrations, BERN Model (medium); source http://www.ipcc-data.org/ancilliary/tar-bern.txt
#Stabilisation scenarios CO2-450 and CO2-550 Sigmoid function between 352ppm in 1990 and the target concentration in 2100.
#Stabilisation function shape based on data scanned from:
#Alan Manne and Richard Richels (1997). On stabilizing CO2 concentrations cost-effective emission reduction strategies. Environmental Modelling and Assessment 2 (1997).
#NB All climate change factors are pattern scaled off the A1B scenario. (NB p subsscript (preliminary) and IS92 are for older scenarios).

Year	A1B	A1T	A1FI	A2	B1	B2	A1p	A2p	B1p	B2p	IS92a	IS92a/SAR	CO2-450	CO2-550	RCP4.5	RCP6.0	RCP3-PD	RCP8.5
1970	325.00	325.00	325.00	325.00	325.00	325.00	325.00	325.00	325.00	325.00	325.00	325.00	325.00	325.00	325.000	325.000	325.000	325.000
1980	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.00	337.000	337.000	337.000	337.000
1990	352.00	352.00	352.00	352.00	352.00	352.00	352.00	352.00	352.00	352.00	352.00	353.00	352.00	352.00	353.000	353.000	353.000	353.000
2000	367.00	367.00	367.00	367.00	367.00	367.00	367.00	367.00	367.00	367.00	367.00	370.00	371.00	368.00	368.865	368.865	368.865	368.865
2010	388.00	386.00	386.00	386.00	386.00	385.00	390.00	388.00	385.00	387.00	387.00	391.00	393.00	389.00	389.128	389.072	389.285	389.324
2020	418.00	410.00	415.00	414.00	410.00	406.00	421.00	416.00	407.00	412.00	413.00	416.00	414.00	414.00	411.129	409.360	412.068	415.780
2030	447.00	435.00	449.00	444.00	432.00	425.00	454.00	447.00	425.00	433.00	439.00	444.00	430.00	440.00	435.046	428.876	430.783	448.835
2040	483.00	466.00	495.00	481.00	457.00	448.00	490.00	484.00	445.00	457.00	468.00	475.00	439.00	467.00	460.845	450.698	440.222	489.435
2050	522.00	496.00	555.00	522.00	482.00	473.00	529.00	525.00	467.00	481.00	499.00	507.00	445.00	490.00	486.535	477.670	442.700	540.543
2060	563.00	523.00	625.00	568.00	503.00	499.00	569.00	571.00	492.00	506.00	533.00	541.00	447.00	510.00	508.871	510.634	441.673	603.520
2070	601.00	545.00	702.00	620.00	518.00	524.00	606.00	622.00	515.00	532.00	568.00	577.00	449.00	525.00	524.302	549.820	437.481	677.078
2080	639.00	563.00	786.00	682.00	530.00	552.00	642.00	683.00	537.00	559.00	607.00	616.00	449.00	536.00	531.138	594.257	431.617	758.182
2090	674.00	572.00	872.00	754.00	538.00	581.00	674.00	754.00	555.00	588.00	653.00	660.00	450.00	544.00	533.741	635.649	426.005	844.805
2100	703.00	575.00	958.00	836.00	540.00	611.00	702.00	836.00	569.00	618.00	703.00	709.00	450.00	550.00	538.358	669.723	420.895	935.874

AR4 IPCC SRES emissions scenarios

Preliminary estimates

Older scenarios

CO_2 stabilisation scenarios

AR5 RCP scenarios

Figure 3.3 Observed (pre 2010) and projected (post 2010) decadal CO_2 concentrations contained in the decadal file (CO2_concentrations_decadal.dat).

Annual CO_2 concentrations (ppm)

```
#AR4 forcings: atmospheric CO2 concentrations, BERN Model (medium); source http://www.ipcc-data.org/ancilliary/tar-bern.txt
#Stabilisation scenarios CO2-450 and CO2-550 Sigmoid function between 352ppm in 1990 and the target concentration in 2100.
#Stabilisation function shape based on data scanned from:
#Alan Manne and Richard Richels (1997). On stabilizing CO2 concentrations cost-effective emission reduction strategies. Environmental Modelling and Assessment 2 (1997).
#NB All climate change factors are pattern scaled off the A1B scenario. (NB p subsscript (preliminary) and IS92 are for older scenarios).
#RCP scenarios are available at http://www.iiasa.ac.at/web-apps/tnt/RcpDb/dsd?Action=htmlpage&page=compare
#Annual values interpolated from decadal values.
```

Year	A1B	A1T	A1FI	A2	B1	B2	A1p	A2p	B1p	B2p	IS92a	IS92a/SAR	CO2-450	CO2-550	RCP4.5	RCP6.0	RCP3-PD	RCP8.5
1970	325.000	325.000	325.000	325.000	325.000	325.000	325.000	325.000	325.000	325.000	325.000	325.000	325.000	325.000	325.000	325.000	325.000	325.000
1971	326.200	326.200	326.200	326.200	326.200	326.200	326.200	326.200	326.200	326.200	326.200	326.200	326.200	326.200	326.200	326.200	326.200	326.200
1972	327.400	327.400	327.400	327.400	327.400	327.400	327.400	327.400	327.400	327.400	327.400	327.400	327.400	327.400	327.400	327.400	327.400	327.400
1973	328.600	328.600	328.600	328.600	328.600	328.600	328.600	328.600	328.600	328.600	328.600	328.600	328.600	328.600	328.600	328.600	328.600	328.600
1974	329.800	329.800	329.800	329.800	329.800	329.800	329.800	329.800	329.800	329.800	329.800	329.800	329.800	329.800	329.800	329.800	329.800	329.800
2094	685.600	573.200	906.400	786.800	538.800	593.000	685.200	786.800	560.600	600.000	673.000	679.600	450.000	546.400	535.588	649.279	423.961	881.233
2095	688.500	573.500	915.000	795.000	539.000	596.000	688.000	795.000	562.000	603.000	678.000	684.500	450.000	547.000	536.049	652.686	423.450	890.340
2096	691.400	573.800	923.600	803.200	539.200	599.000	690.800	803.200	563.400	606.000	683.000	689.400	450.000	547.600	536.511	656.093	422.939	899.446
2097	694.300	574.100	932.200	811.400	539.400	602.000	693.600	811.400	564.800	609.000	688.000	694.300	450.000	548.200	536.973	659.501	422.428	908.553
2098	697.200	574.400	940.800	819.600	539.600	605.000	696.400	819.600	566.200	612.000	693.000	699.200	450.000	548.800	537.435	662.908	421.917	917.660
2099	700.100	574.700	949.400	827.800	539.800	608.000	699.200	827.800	567.600	615.000	698.000	704.100	450.000	549.400	537.896	666.316	421.406	926.767
2100	703.000	575.000	958.000	836.000	540.000	611.000	702.000	836.000	569.000	618.000	703.000	709.000	450.000	550.000	538.358	669.723	420.895	935.874

1970 to 2100

AR4 IPCC SRES emissions scenarios

Preliminary estimates

Older scenarios

CO_2 stabilisation scenarios

AR5 RCP scenarios

Figure 3.4 A snapshot of information contained in the annual CO_2 concentrations data file (CO2_concentrations_annual.dat).

3.4 Log warning files

Log warning files (see naming convention below) accompany the CF data, for each point-location and model run. The log warning files hold information to alert users to any problematic data. For example, data are generated for inclusion in log warning files when projections data lie outside the bounds of what may reasonably be expected.

The log warning files are typically named:

LocationCode_Latitude_Longitude_VersionNo.log

e.g. 056002_-30.5167_151.6681_V1.2.log

- LocationCode is a six digit number (BoM station code if patched-point, i.e. 051039, *or all zeros if drilled (from interpolated surfaces), i.e. 000000*)
- Latitude (of the station or location in decimal degrees)
- Longitude (as above)
- VersionNumber (V1.2 represents CF data)

The log warning files include:

- ModelName (i.e. CSIRO-MK35, HADGEM1, HI, HP, etc.)
- Emissions 'Scenario' (A1FI, A1B, A1T, A2, B1, B2, CO2_450 or CO2_550)
- Climate Warming sensitivity (low, median or high)
  - 'L', 'M' and 'H' refer to the 10th, 50th and 90th percentile values respectively
- Projections year (2030 or 2050)
- Number of projected Tmin greater than projected Tmax
  - Instances when the projected minimum temperature is greater than the maximum projected temperature for the day.
- Number of projected Vp greater than VpSat
  - Instances where the projected vapour pressure is checked against the saturated vapour pressure using WMO 2008 recommended functions without pressure corrections.
- Number of clamped projected radiation greater than ET radiation
  - Instances where the projected radiation are clamped to 0.81% of the calculated extra terrestrial maximum solar radiation on a horizontal surface and clear sky radiation.
- Warning: Potential (or Implausible) Extreme Percent Change Rate
  - Month affected
  - Climate element affected (i.e. rain)
  - Change from the historical baseline climate as a percentage change for rain, radiation, relative humidity and pan evaporation, but an absolute change for temperature, e.g. for rain a change of -75, means a 75 percent decline.

The thresholds for which log warnings are assessed are presented in Table 3.1.

Table 3.1 Thresholds for which log warnings are assessed.

Warning Values

Element	Warning High value	Warning Low value	Implausible High value	Implausible Low value
Rain	> + 50%	< -50%	> +90%	< -90% RESET to -90%
Radiation	> + 50%	< -50%	> +90%	< -90% RESET to -90%
Relative Humidity	> + 50%	< -50%	> +90%	< -90% RESET to -90%
Maximum Temperature	> +7°C	< -2°C	> +8°C	< -3°C
Minimum Temperature	> +7°C	< -2°C	> +8°C	< -3°C
Pot. Evaporation	> + 50%	< -50%	> +90%	< -90% RESET to -90%

A snapshot of information contained in a log warning ancillary data file is shown in Figure 3.5.

```
Warning: Potential Extreme Percent Change Rate  INMCM Precipitation 2050 high A1FI Sep -51.93
Warning: Potential Extreme Percent Change Rate  INMCM Precipitation 2050 high A1FI Nov -52.11
ECHAM5_A1B_med_2050 Number of projected Tmin greater than projected Tmax;  0
ECHAM5_A1B_med_2050 Number of projected synthetic evaporation less than 0:  0
ECHAM5_A1B_med_2050 Number of projected Vp greater than Vp Saturated:  0
ECHAM5_A1B_med_2050 Number of clamped projected radiation greater than ET radiation:  0
Warning: Potential Extreme Percent Change Rate  CCCMA-47 Precipitation 2050 high A1T Oct -52.01
Warning: Potential Extreme Percent Change Rate  CCCMA-47 Precipitation 2050 high A1FI Oct -55.05
Warning: Potential Extreme Percent Change Rate  CSIRO-Mk30 Precipitation 2050 high A1T Jun -59.71
Warning: Potential Extreme Percent Change Rate  CSIRO-Mk30 Precipitation 2050 high A1T Aug -52.10
```

Figure 3.5 Snapshot of information contained in a log warning ancillary data file (filename 056002_-30.5167_151.6681_V1.2.log).

For example, ‘Potential Extreme Percent Change Rate’ will be listed in a log warning file if the application of the ‘change factor’ produces more than a 50% decline in projected rainfall from the historical baseline climate. In this case no adjustment is made to the rainfall projections data, but users need to be cautious if applying that data in any modelling study.

An ‘Implausible Extreme Percent Change Rate - CLAMPED’ will be listed in a log warning file if the application of the ‘change factor’ obtained from the pattern scaling produces more than a 90% decline in projected rainfall from the historical baseline climate. In this case the rainfall projections data are clamped at 10% of the baseline climatology values, to avoid occurrence of negative rainfall.

Information about limitations related to the capture of anomalous data in the Log Warning files, is presented in Section 10.2.

Notes

- *Users should note that the precision of the values listed in the Log warning files is for calculation purposes only and will not occur in reality.*
- *In some cases (usually individual days) anomalous values may occur. These values may be derived from one of three sources, which are: 1) the raw data, 2) interpolation, or 3) the modification to "climate changed data".*

3.5 Historical time series plots

Historical time series plots, for the six climate variables used in the CCS project, have been provided as part of the user information framework. The plots provide users with representations for specific locations showing the historical annual variability, as well as a longer-term trend (i.e. rising mean annual temperature).

The plots are location-specific and show the daily average for each year, as an annual time series, extracted from historical SILO climate data**.**

Although users can select any period from 1960 onwards, 1960 to 2010 is the recommended historical baseline. Periods of less than 30 years are insufficient for climate-change trend analysis.

The historical time series plots are .png files and are typically named:

LocationCode_Lat_Long_V1.2.png

e.g. 040112_-26.5544_151.8456_V1.2.png

- LocationCode is a six digit number (BoM station code if patched-point, i.e. 040112, *or all zeros if drilled (from interpolated surfaces), i.e. 000000*)
- Latitude (of the station or location in decimal degrees)
- Longitude (as above)
- VersionNumber (V1.2 represents CF data)

A snapshot of a historical time series plot is presented in Figure 3.6.

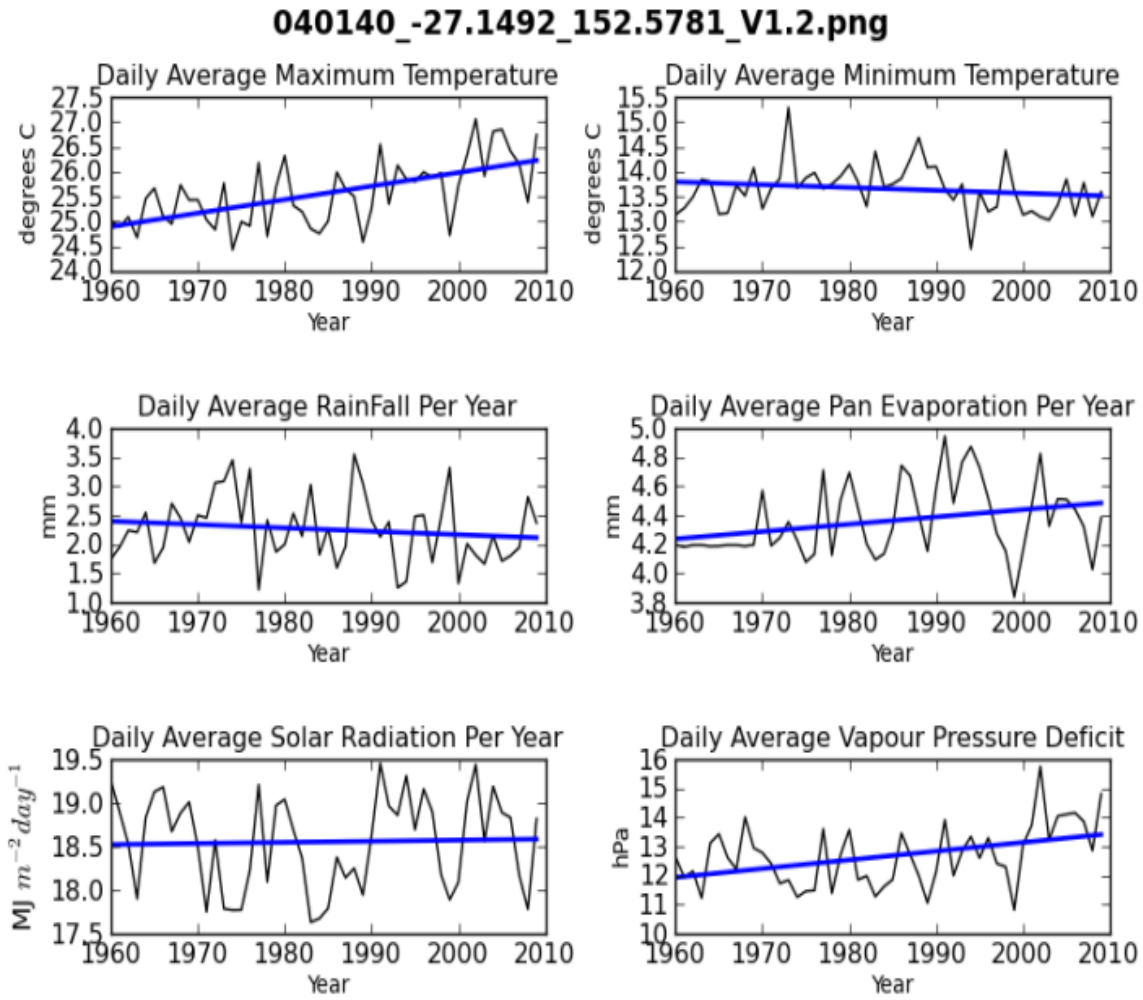


Figure 3.6 Historical time series plot for Mt Brisbane, Queensland (LocationCode 040140), (filename: 040140_-27.1492_152.5781_V1.2.png). Annual variability is shown is black. The linear trend for the selected base period (in this case 1960-2010) is shown in blue. Historical time-series plots are not produced for periods of less than six years.

Notes

- *Pan evaporation data from 1970 onwards are from daily 'class A' pan evaporation measurements. Prior to this the data is synthetic pan.*
- *Linear trend lines showing the selected long-term trend are not plotted for periods of 30 years or less.*
- *The historical time-series plots are not produced for periods of less than six years.*

3.6 CF Frequency distribution plots

CF v1.1 based frequency distribution plots, based on the A1B emissions scenario for six climate variables, were initially provided as test data as part of the user information framework for the Consistent Climate Scenarios project. The plots provide users with a visual impression of historical and projected frequency distribution changes. Initial inspection of the plots shows that the output is as expected (i.e. increased temperatures). These plots are not currently available through the CCS web-portal (see Section14 for contact details).

The plots are designed to inform users of the change in frequency distributions (shown on the y-axis) for both the observed (1960-2009 baseline) and the projected (2050) climate data. The frequency distribution plots provide users with an analysis of the occurrence of discrete values of specified climate variables, expressed as a percentage of the total distribution for that variable.

The CF based frequency distribution plots are not provided with the CF V1.2 datasets via the web Climate Change Projections web portal, as not all users will request the A1B scenario with their data order. However, plots are for specific locations in Australia and can be made available on request for 17 GCMs, the A1B emissions scenario, high climate warming sensitivity and six climate variables. The climate variables are:

- rainfall
- maximum and minimum temperature
- solar radiation
- vapour pressure
- pan evaporation.

The frequency distribution plots are .gif files and are typically named:

ModelName_Scenario_ClimateSensitvity_ProjectionsYear_LocationCode_Lat_Long_fdist_v1.1.gif

e.g. CSIRO-Mk35_A1B_H_2050_051039_-31.5495_147.1961_fdist_v1.1.gif

- ModelName (BCCR, CCCMA-47, CCCMA-63, CNRM, CSIRO-MK30, CSIRO-MK35, ECHAM5, ECHO-G, GFDL-20, GFDL-21, GISS-AOM, HADCM3, HADGEM1, IAP-FGOALS, INMCM, MIROC-H, MIROC-M, MRI-GCM232, NCAR-CCSM)
- Scenario (emissions scenario: A1B)
- Climate Warming sensitivity (high)
  - 'H' refers to the 90th percentile value
- Projections year (2050)
- 'LocationCode' is a six digit number (BoM station code if patched-point, i.e. 051039, *or all zeros if drilled (from interpolated surfaces), i.e. 000000*)
- Latitude (of the station or location in decimal degrees)
- Longitude (as above)
- fdist (frequency distribution file)
- VersionNumber (v1.1 represents CF data)

Change in frequency is greatest where there are large differences between the observed (coloured) and projected (black) points on the plots.

A snapshot of a frequency distribution plot is presented in Figure 3.7.

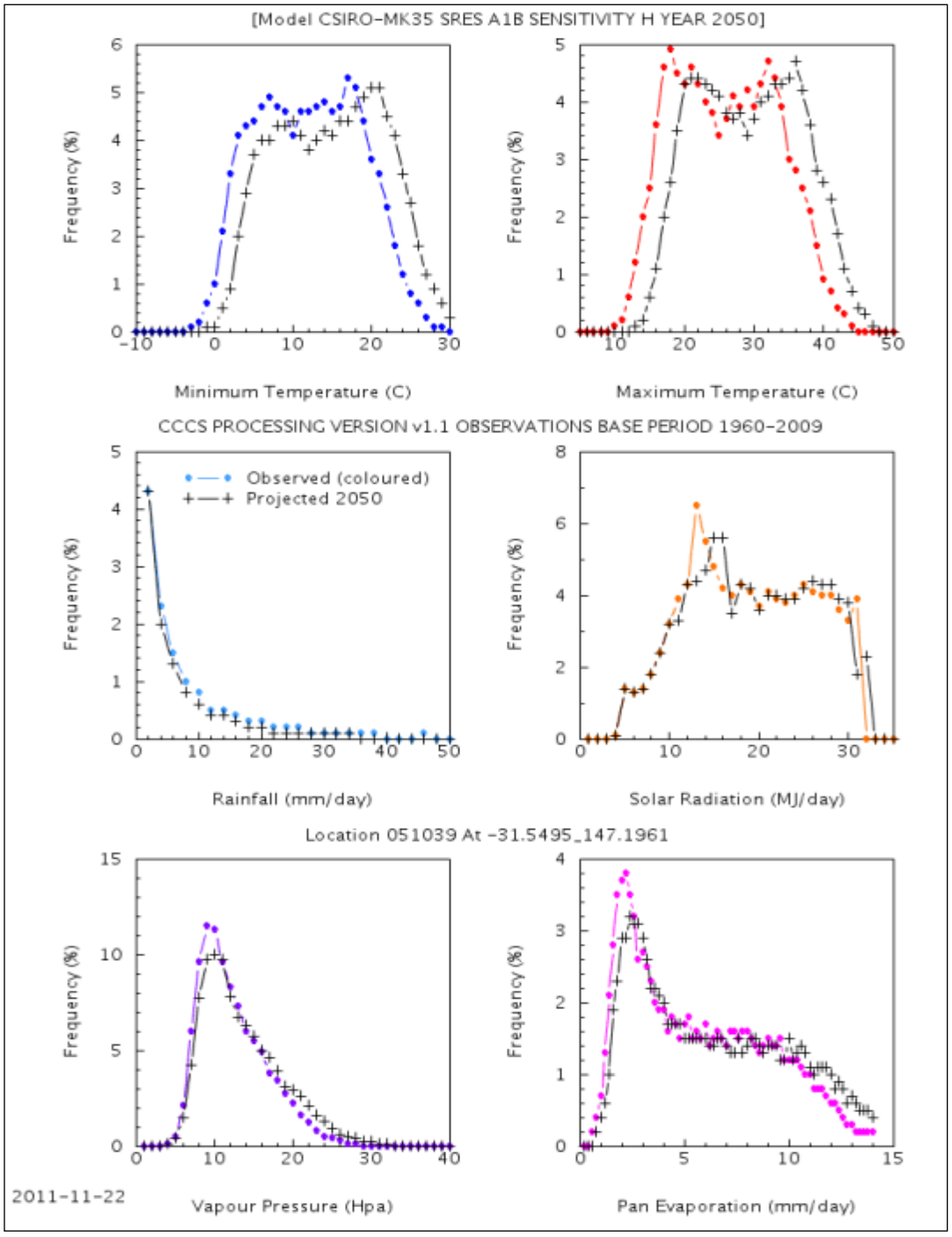


Figure 3.7 Frequency distribution plots, observed with 2050 projections, for Nyngan Airport (LocationCode 051039) in South Australia (filename CSIRO-MK35_A1B_H_2050_051039_ -31.5495_147.1961_fdist_v1.1.gif), from a run of the CSIRO-Mk3.5 GCM forced by the A1B emissions scenario with high climate warming sensitivity. Observed values are coloured, projections are shown in black.

Spikes in pan evaporation frequency distribution plots

Bureau of Meteorology Class A pan evaporation site data has been used since 1970. Bird cages were installed then, to reduce errors, (e.g. evaporation readings were occasionally too high, due to animals drinking or splashing water). The frequency spikes that occur in the observed pan evaporation frequency distribution plots are due largely to lack of precision in some (post 1970) manually recorded observations. For example, during measurement, evaporation has been rounded down to the nearest full can (which holds 4 mm), giving spikes at 4 mm and 8 mm on the x-axis, rather than providing more precise values. Spikes in the observed data also occur on high rainfall days, especially if the pan overflows, or there is a reading error in the rainfall, which is subsequently transferred to the pan reading.

3.7 Comparison of model projections plots

Comparison of model projections plots are provided, in the ZIP archives, as part of the user information framework, to assist users in GCM model selection.

Each plot is location specific and shows projected changes (i.e. climate 'change factors') at 2030 from a 1960-2010 base period climate, for both annual mean temperature and rainfall. The changes in temperature and rainfall are presented for each of 19 GCMs and three climate warming sensitivities (low, median and high). The GCMs were all forced by the A1B emissions scenario.

The projected changes have been calculated using amounts of global warming from MAGICC applied to the mean annual rate of change for rainfall and temperature per degree of global warming.

On each plot:

- change in annual mean rainfall is shown on the x-axis
- change in annual mean temperature is shown on the y-axis
- GCM model names are abbreviated (i.e. CCCMA, GISS)
- the mean change from the 1960 to 2010 base period for the aggregate of all seventeen GCMs models is shown by the blue circle
- changes in the median, from the base period, for individual models are shown by red squares
- changes in rainfall, based on 10^{th} and 90^{th} percentile climate warming sensitivities are indicated by the horizontal barbs
- changes in temperature for 10^{th} and 90^{th} percentile climate warming sensitivities are indicated by the vertical barbs.

The comparison of model projections plots are .gif files and are typically named:

LocationCode_Scenario_ClimateSensitvity_ProjectionsYear_Lat_Long_mdlperf_V1.2.File Type

e.g. 014901_A1B_M_2030_-13.8345_131.1872_mdlperf_V1.2.png

- LocationCode is a six digit number (BoM station code if patched-point, i.e. 014901, *or all zeros if drilled (from interpolated surfaces), i.e. 000000*)
- Scenario (emissions scenario: A1B)
- Climate Warming sensitivity (default 'M' place holder only)
- Projections year (2030)
- Latitude (of the station or location in decimal degrees)
- Longitude (as above)
- mdlperf (model performance: comparison of model projections file)
- VersionNumber (V1.2 represents CF data)
- FileType (.gif for v1.1 or .png for V1.2)

A snapshot of a comparison of model projections plot, based on the climate 'change factor' methodology, is presented in Figure 3.8.

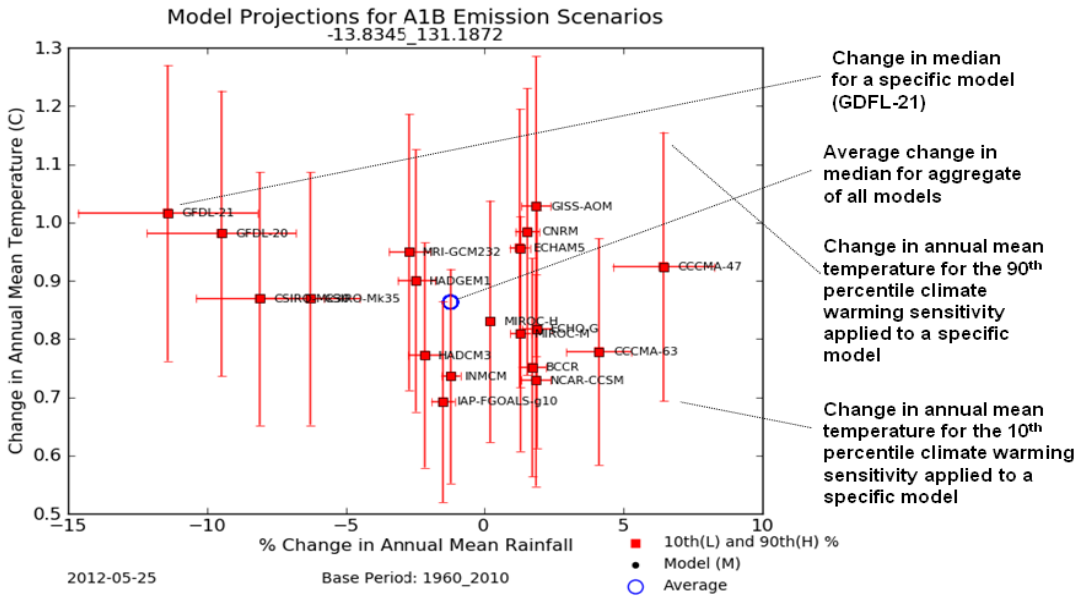


Figure 3.8 Comparison of model projections plot for 2030 for Douglas River (LocationCode 014901) in Northern Territory. Plot generated using Version 1.2 projections data climate 'change factors' for GCMs forced by the A1B emissions scenario (filename 014901_A1B_M_2030_-13.8345_131.1872_mdlperf_V1.2.png).

Note

- *GCMs with large changes in annual mean temperature tend to have a wide range of uncertainty between the 10th and 90th percentile values for both temperature and rainfall. The uncertainty range between the 10th and 90th percentile values is smaller where GCMs have less change in the annual mean temperature.*

3.8 Plots of simulated 20th and 21st Century climate

Plots of GCM simulated 20th and 21st Century climate were initially made available for a selection of 23 AR4 A1B forced GCM runs (see Section 8, Table 8.2), with CF (Version 1 and Version 1.1) Consistent Climate Scenarios datasets.

The plots, which also provide some indication of projected climate variability, are now contained in a draft document entitled, “Comparisons of Australian continental area-weighted mean rainfall and temperature, and global mean temperature according to available AR4 A1B forced GCM runs”.

Each plot included graphs showing time-series of the observed and GCM simulated 20th Century and GCM simulated 21st Century for:

- Australian continental area-weighted mean rainfall;
- Australian continental area-weighted mean temperature; and
- global mean temperature.

The monthly mean precipitation and temperature data used to produce the Australian continental graphics were accessed from DSITIA copies of the IPCC CMIP3 data set. For the comparisons of global mean temperature according to available GCM runs, the measured series (1901-2009), initially provided as anomalies from the 1951-1980 base period, were taken unmodified from GISS GLOBAL Land-Ocean Temperature Index in 0.01ºC (sources being GHCN 1880-2010+SST and 1880-11/1981 HadSST1).

These graphs are based on output from individual GCM runs which have not been re-scaled or normalised in any way (and are not based on the ‘Consistent Climate Scenarios’ projections data).

Snapshots of information contained in continental area-weighted rainfall and temperature and global mean temperature files are presented in Figures 3.9, 3.10 and 3.11 respectively.

On the Australian continental area-weighted rainfall and mean temperature graphs, the observed annual data (Obs, shown by the purple line) and GCM simulated data (20C, shown by the blue line) cover the 20th Century. The yellow and dark green regression lines represent the observed and simulated 20th Century trends respectively. 21st century GCM projections (21C) are shown by the red (annual variability) and light blue (100 year trend) lines.

On the observed global mean temperature graphs, the annual air temperature (Obs (GISS)) is shown by the red line and covers the time-span of measured data to present. The GCM simulated data (20C (Model)) shown by the blue line cover the 20th century. 21st Century GCM projections (21C (Model A1B)) are shown by the green line.

Statistics presented on the graphs include:

- slope 20th and 21st Century (positive for an increase, negative for a decrease)
- Pr probability of rainfall or temperature trend being zero (< 0.05 is significant)
- mean 20th and 21st Century mean annual rainfall or temperature
- mse mean standard error of annual rainfall or temperature
- cv coefficient of variation of the mean annual rainfall or temperature
- r: regression coefficient
- intercept intercept on the y-axis, where year = 0

The yellow shading indicates periods where GCMs have both daily and monthly data. Many GCMS do not have daily data prior to 1945.

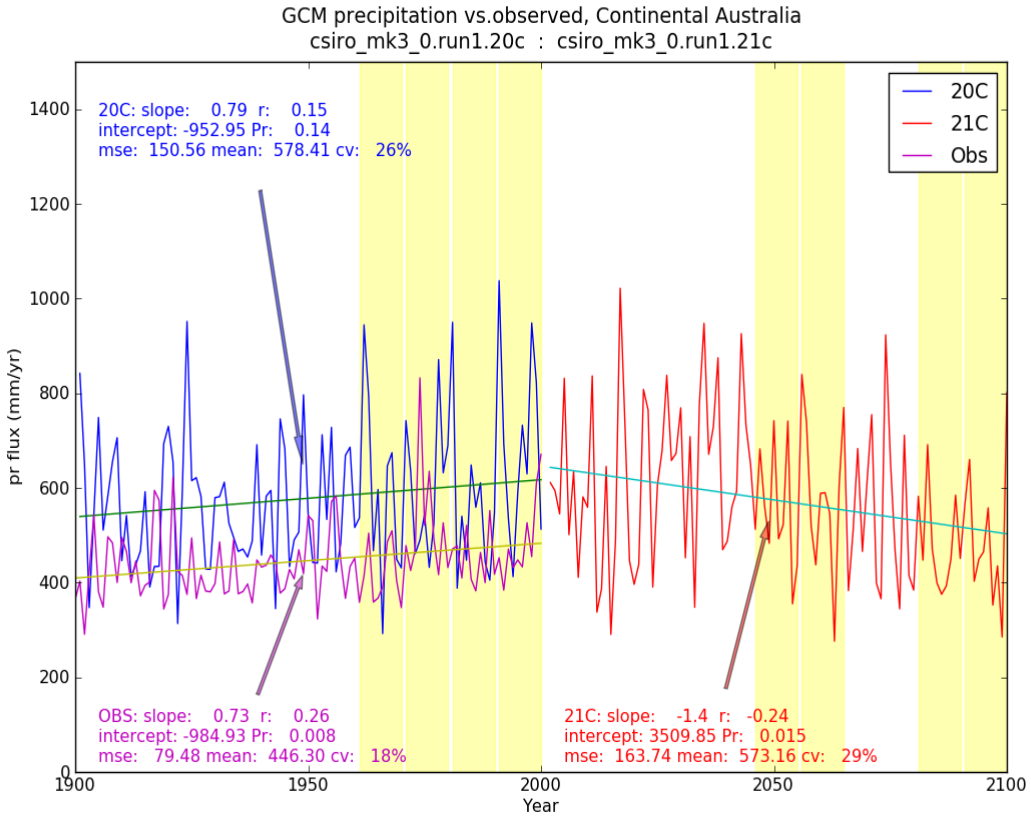


Figure 3.9 Time series presented in a continental area-weighted mean rainfall file (filename CSIRO-Mk30.pr.run1.png) for CSIRO-Mk3.0 with the A1B emissions scenario. This run shows a decrease in Australian continental weighted rainfall in the 21st Century. Yellow bands represent periods for which DSITI holds daily information for that GCM.

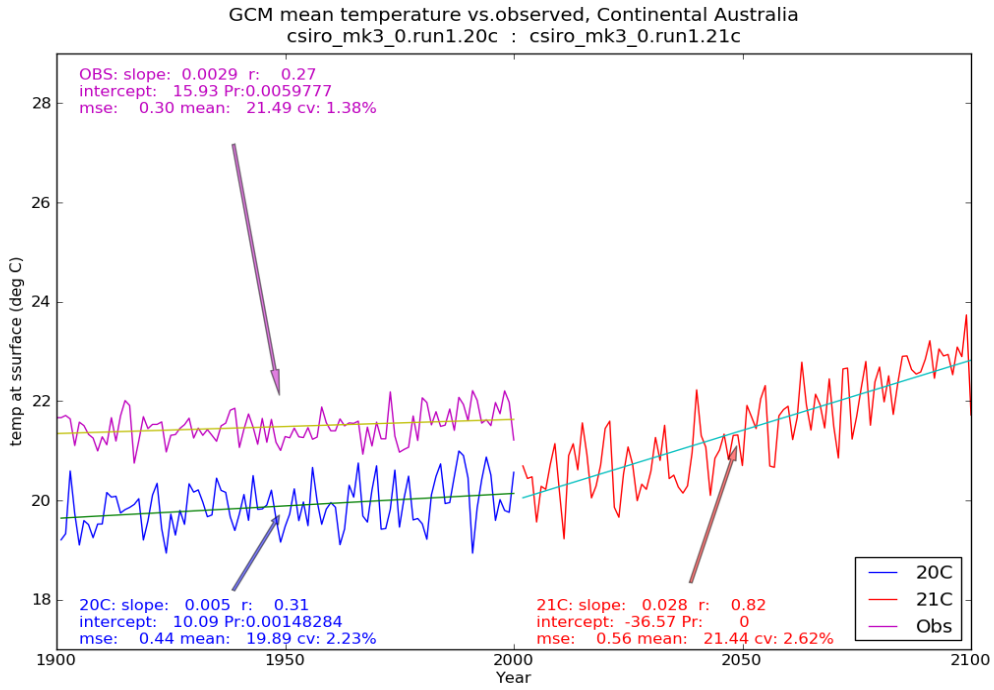


Figure 3.10 Time series presented in a continental area-weighted temperature file (filename CSIRO-Mk30.tas.run1.png) for CSIRO-Mk3.0 with the A1B emissions scenario. This run shows a marked increase in Australian continental weighted mean temperature in the 21st Century.

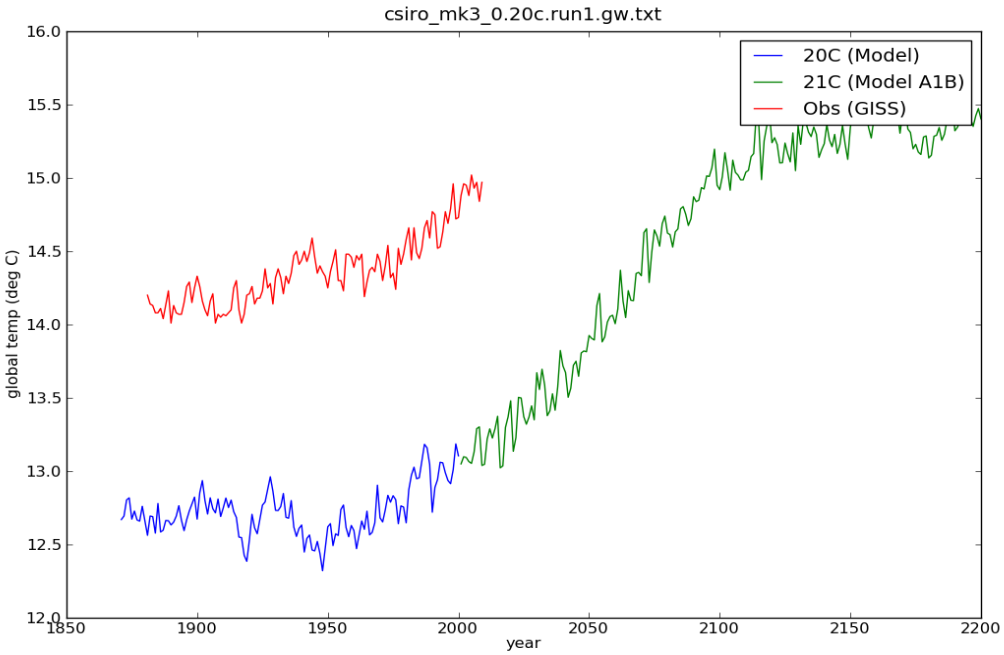


Figure 3.11 Time series presented in a global mean temperature file (filename CSIRO-Mk30.gw.run1.png) for CSIRO-Mk3.0 with the A1B emissions scenario. This run shows a marked increase in global mean temperature in the 21st Century.

3.9 Quantile trend plots

If diagnostics are selected, when ordering through the web-portal, the QM 2030 datasets will include plots of location-specific quantile[3] trends. QM 2050 quantile trend plots can be downloaded via **ftp://climate.mft.derm.qld.gov.au/Climate_Scenarios/QM_2050_TestData/**. These are the trends that have been used to estimate target cumulative distribution frequencies (CDFs) for 2030 for projected rainfall, maximum temperature, minimum temperature, solar radiation and specific humidity (or their transforms) and target CDFs for 2050 for solar radiation and specific humidity.

The plots are arranged by month and show historical time-series for quantiles 0.1, 0.5 and 0.9, of daily data for each month, including1957 to 2010 training-period linear trends as well as forward extrapolation of these trends (to 2030/2050). Computed statistical significance of each trend (represented by p-values) over the training period is given as well for each climate variable,

Quantile trends have been classed as significant when the computed statistical significance, called the p-value statistic (shown on each graphic) is 0.1 or less (i.e. when there is at most a 10 per cent probability that the observed data arose from an underlying stationary distribution). If a computed p-value for a quantile trend exceeds the 0.1 cut-off, the trend is not used in the QM projections and no trend is applied. This represents a null model in which the future quantiles are the same as those over the training period.

In the QM processing, corrections are made in cases where future trends would cross. This does not apply to rainfall and temperature variables in the QMV2.2.10 datasets for 2050 which utilise a future CDF based on daily GCM data and not trend extrapolation, but does apply to QM 2050 solar radiation and specific humidity for which future CDFs *are* estimated using trend extrapolation.

The quantile trend plots are .png files and are typically named:

ClimateVariable_LocationCode_PivotQuantiles_1957_2010_ProjectionsYear_QuantileTrends_LocationCode.png

e.g. T.Min_040428_[10,50,90]_1957_2010_2030_QuantileTrends_040428.png

- ClimateVariable
  - RadnPropOfEtlogit (solar radiation transformed by ground level proportion of extra-terrestrial, then logit transform used)
  - RainCubeRoot (rainfall transformed by cube root)
  - SH (specific humidity transformed from vapour pressure)
  - T.Max (maximum temperature, no transform)
  - T.Min (minimum temperature, no transform)
- LocationCode is a six digit number (BoM station code if patched-point, i.e. 002012, *or all zeros if drilled (from interpolated surfaces) i.e. 000000*)
- PivotQuantiles [10,50,90] denotes 0.1, 0.5 and 0.9 quantiles
- 1957_2010 (historical training period)

[3] Quantiles differ from percentiles, in that quantiles are expressed in sample fractions rather than sample percentages. Quantile 0.1 is equivalent to the 10th percentile.

- 2030 (projections year)
- QuantileTrends (denotes Quantile trend plot file)

A snapshot of a quantile trend plot is presented in Figure 3.12.

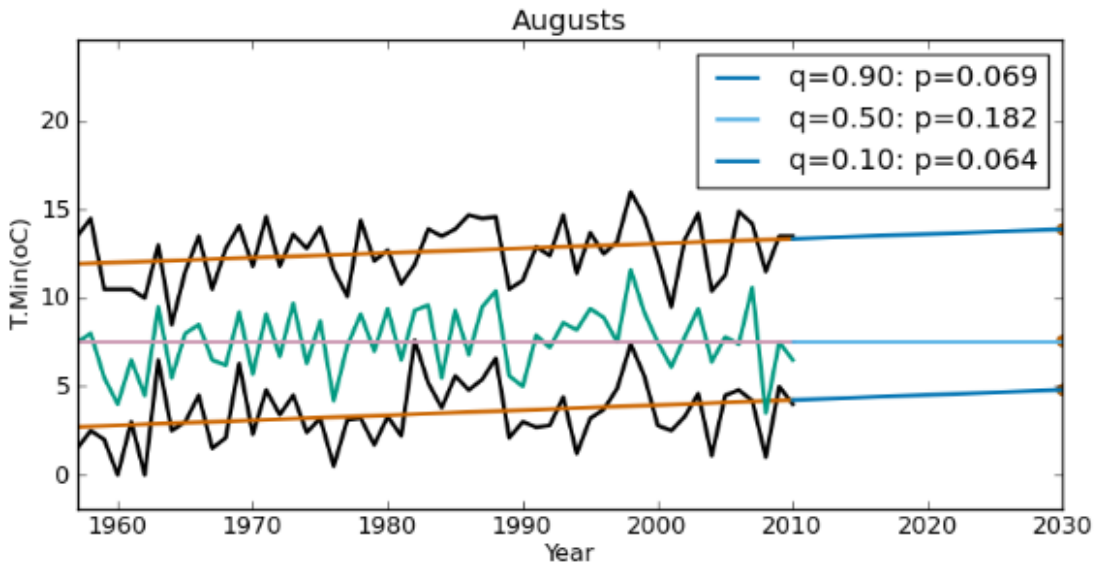


Figure 3.12 An example from a quantile trend plot for a specific showing time series for the 0.1, 0.5 and 0.9 quantiles (and the statistical significance, i.e. p-values) of daily minimum temperature for Augusts, with trends computed over the 1957-2010 period location (filename: T.Min_040428_[10,50,90]_1957_2010_2030_QuantileTrends_040428.png). Plotting scales may change between stations.

Notes

- Where observed quantile trends are statistically significant ($p < 0.1$), the 'quantile-matched' approach is used to produce the 2030 rainfall, temperature, solar radiation and specific humidity projections data and the 2050 solar radiation and specific humidity data.
- Where observed quantile trends are not significant, the climate projections method defaults to the 'change factor' approach for the above-mentioned climate variables.

3.10 Histograms of 'quantile-matched' climate projections

If diagnostics are selected, when ordering through the web-portal, the QM 2030 datasets will include plots of histograms of QM climate projections. QM 2050 quantile trend plots can be downloaded via **ftp://climate.mft.derm.qld.gov.au/Climate_Scenarios/QM_2050_TestData/**.

These histograms, arranged by month, are location-specific and show frequency distributions for specified climate variables (or their transforms). The frequency distributions include 'quantile-matched' 2030 or 2050 projections data in comparison to an observed 1957-2010 baseline climate.

Months where no significant quantile trends are computed will be apparent in the histogram plots as a simple horizontal translation between the historical (black shaded) and 'quantile-matched' (orange shaded) data, due to OzClim 'change factor' based trends only.

The means (μ) and sample standard deviations (s_N) of the historical and 'quantile-matched' data are shown on each plot.

Users should note that the plotting scales may differ between stations.

The histograms are .png files and are typically named:

ClimateVariable_LocationCode_PivotQuantiles_1957_2010_ProjectionsYear_Histograms_LocationCode_ModelName_Scenario_ClimateWarmingSensitivity.png

e.g.

T.Min_040428_[10,50,90]_1957_2010_2030_Histograms_040428_HADCM3_A1FI_high.png

- ClimateVariable
  - Radn (solar radiation transformed by ground level proportion of extra-terrestrial, then logit transform used)
  - Rain (rainfall not-transformed)
  - RainCubeRoot (rainfall transformed by cube root)
  - VP (transformed to specific humidity, then back to vapour pressure)
  - T.Max (maximum temperature, no transform)
  - T.Min (minimum temperature, no transform)
- LocationCode is a six digit number (BoM station code if patched-point, i.e. 002012, *or all zeros if drilled (from interpolated surfaces), i.e. 000000*)
- PivotQuantiles [10,50,90], denotes 0.1, 0.5 and 0.9 quantiles
- 1957_2010 (historical training period)
- Projections year (2030 or 2050)
- Histograms (denotes Histograms trend plot file)
- Model Name (i.e. CSIRO-MK35)
- Scenario (emissions scenario, i.e. A1B, A1FI, etc.)
- Climate warming sensitivity (rate of global warming) i.e. low, med, high, referring to the 10^{th}, 50^{th} and 90^{th} percentile values respectively.

A snapshot of a quantile-based historgam is presented in Figure 3.13.

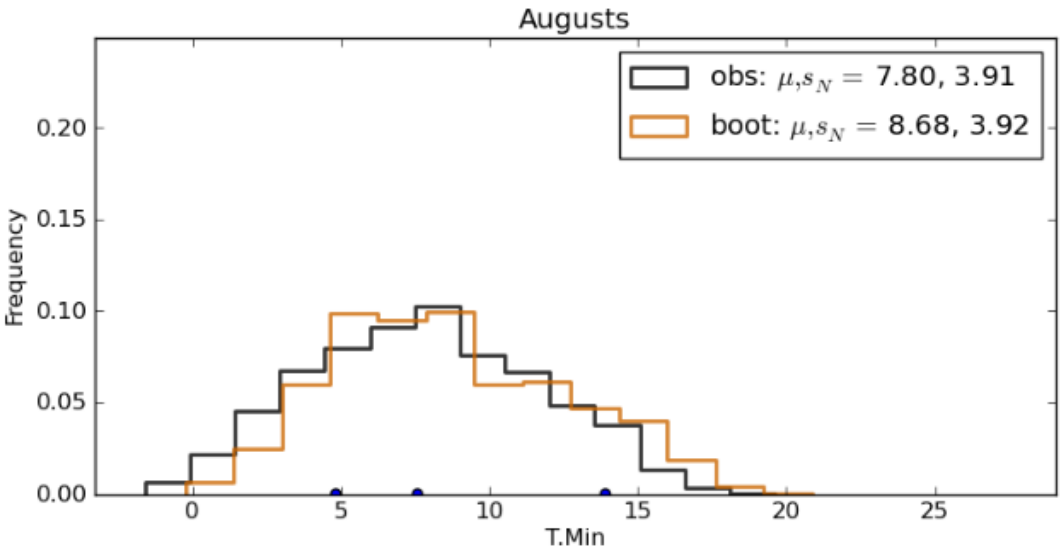


Figure 3.13 Minimum temperature information displayed in a histogram of 'quantile-matched' (QM) projections data for Augusts for a specific location, showing differences between the observed 1957 to 2010 baseline climate and QM 2030 climate projections data. This plot (filename: T.Min_040428_[10,50,90]_1957-2010_2030_Histograms_040428_HADCM3_A1FI_high.png) shows a positive shift in the QM frequency distribution. The blue semi circles on the x-axis represent projected 10th, 50th and 90th percentile values of the mean daily minimum temperature for 2030, using QM trends. Observed 1957-2010 and projected 2030 means and corresponding standard deviations are presented in the top right panel.

Notes

- *Where observed quantile trends are significant (p <0.05), the QM approach is used to produce the 2030 rainfall, temperature, solar radiation and specific humidity projections data and the 2050 solar radiation and specific humidity data and the projected standard deviation shown in the plot will differ from that of the historical baseline data.*
- *Where observed quantile trends are not significant, the climate projections method defaults to the 'change factor' approach for the above-mentioned climate variables and the projected standard deviation shown in the plot will be the same as that of the historical baseline data.*

3.11 Transient climate data test set for 1889-2100

A test set of transient climate change files, and background documentation, are located in a zip archive named **transient_data_test_set.zip** at

ftp://climate.mft.derm.qld.gov.au/Climate_Scenarios/Transient_TestData/

The transient climate change files contained within the zip archive are named as follows:

e.g. 035149_-24.8353_149.8003_NCAR-CCSM_CO2-550_med_CF1.2EM09.wth

- Station number, also called Location Code (035194)
- Latitude of the station in decimal degrees (24.8353 South)
- Longitude of the station (149.8003 East)
- GCM Model Name (17 are available, i.e. NCAR_CCSM)
- SRES emissions scenario (eight are available, i.e. CO2-550)
- Climate warming sensitivity (i.e. low, med, high), referring to the 10th, 50th and 90th percentile values respectively.
- Projections Method Code and Version (CF 1.2)
- Ensemble Code (EM)
- Ensemble number
  - e.g. 01 starting point 1962
  - 02 " " 1963
  - 03 " " 1968
  - 04 " " 1972
  - 05 " " 1975
  - 06 " " 1985
  - 07 " " 1986
  - 08 " " 1996
  - 09 " " 2001
  - 10 " " 2009
- File type (transient climate data .wth)

The transient climate change files have been constructed for a single location (Brigalow Research Station, Central Queensland), and formatted for use in the CENTURY model, as "proof of concept", prior to further systems development.

The transient climate change files include historical data back to 1889 and CF based projections data to 2100. The test data are for the same range of seventeen GCMs, eight emissions scenarios and three climate warming sensitivities as the CF Version 1.1 2030 and 2050 projections datasets. Ten ensemble members, with starting years between 1962 and 2009 are provided.

The data files contain the projections year, and for each month, precipitation total, mean daily minimum and mean daily maximum temperatures, and at the end of each data row, the source year, the index (1-10) to the analogue start year, and the expected degrees of global warming (ºC). These extra data fields are not read by the CENTURY model and are for diagnostic purposes in this data set.

An example of information presented in a transient climate change data file is presented in Figure 3.14.

```
prec  2098   7.44   5.72   4.84  20.27  36.29   3.32   4.37   2.61   0.61  11.00  14.33   4.67 1983 02   2.400
tmin  2098  21.85  23.83  22.12  18.29  17.59  11.12   9.77  11.52  14.87  17.82  19.83  19.95 1983 02
tmax  2098  36.29  38.40  34.64  30.99  25.84  22.46  24.07  24.14  31.42  31.81  31.87  33.53 1983 02
prec  2099  10.15   1.77   7.62   2.37   1.74   1.54  11.87   1.73  20.20  15.30   1.42  13.56 1984 02   2.420
tmin  2099  22.89  22.34  20.61  17.30  12.67  10.74  10.23   9.39  12.54  15.95  18.79  21.91 1984 02
tmax  2099  34.37  35.12  33.58  31.30  27.25  24.82  23.60  25.25  28.03  29.15  32.77  35.75 1984 02
prec  2100   4.17  13.35   2.58   2.02   5.39   4.90   3.08   3.83   3.37  11.37   4.69  14.22 1985 02   2.430
tmin  2100  22.07  24.05  21.99  17.44  14.85   8.42   9.87  10.60  13.08  16.41  20.87  22.47 1985 02
tmax  2100  36.84  36.61  34.32  32.05  27.40  23.28  24.88  26.55  29.54  30.15  33.10  36.53 1985 02
```

Figure 3.14 A snapshot of information presented in a transient climate change data file, suitable for use in CENTURY (filename 035149_-24.8353_149.8003_NCAR-CCSM_CO2-550_med_CF1.2EM09.wth).

In addition to the transient climate change data files, the zip archive includes multiplier files, from which ‘change factors’ have been calculated. The multiplier files, which are described in Section 3.1 of this User Guide, are named as follows:

LocationCode_Latitude_Longitude_VersionNo.multiplier

e.g. 035149_-24.8353_149.8003_v1.2.multiplier

4 'Change factor' (CF) methodology

This section of the User Guide describes the methodology, employed by CSIRO, to prepare the OzClim climate 'change factors' (CSIRO, 2010). The section also outlines how climate 'change factors' are applied to historical data to produce climate estimates for the future.

The climate 'change factors' used to calculate CCS data have been estimated using

- Coupled Model Intercomparison Research Program 3 (CMIP3) patterns of change data (projected changes per degree of 21st Century global warming) supplied by the CSIRO and the UK Met Office/Hadley Centre; and
- data from SRES scenario temperature response curves (projected amounts of global warming) supplied by the CSIRO.

4.1 'Change factor' definition

The term climate 'change factor' refers to the change in the climatological mean of a specific climate variable (e.g. temperature) between the current climate (defined in terms of a suitable 20th Century base period) and a projected time in the future (for example, the 30 years centred on 2050).

Calculated on a monthly basis, 'change factors' may be used as scalars to transform historical daily climate time-series to produce time-series of projected future climate for use in biophysical models. Climate 'change factors' have been calculated, using the OzClim[4] methodology, and applied to SILO historical baseline climate data to produce the Consistent Climate Scenarios CF (Version 1,Version 1.1 and Version 1.2) projections datasets for 2030 and 2050. In OzClim, 'change factors' are applied to a 1975 to 2004 baseline climate (CSIRO, 2010).

4.2 Background

The CMIP3 (Coupled Model Intercomparison Project 3) database includes experiments from the 23 GCM models submitted to the International Panel for Climate Change (IPCC) Fourth Assessment Report (AR4). IPCC AR4 represents a global scientific consensus on the issue of climate change and is accepted as the highest authority for policy makers. The CMIP3 database has been freely available to the global research community resulting in unprecedented levels of evaluation and analysis.

OzClim (CSIRO, 2010) is a CSIRO product, used to explore climate change scenarios from 2020 to 2100 for Australia and has an interactive website at http://www.csiro.au/ozclim. OzClim provides climate change projections information based on the results of experiments from 23 GCM projections, which are a subset from the International Panel for Climate Change Fourth Assessment Report (IPCC AR4).

For any one GCM, the experiments in the CMIP3 database do not cover the full range of emissions scenarios (eight) which were considered by the IPCC in its

[4] OzClim version 3

Special Report on Emissions Scenarios (SRES) (IPCC, 2000). The experiments also did not include a desirable level of replication.

The IPCC employed a relatively straight-forward methodology to extrapolate AR4 model outputs across all SRES scenarios and to quantify the sensitivity of the warming response to a particular emissions scenario. This method involves the use of a coupled gas/climate model called MAGICC (Model for the Assessment of Greenhouse-gas Induced Climate Change) (Wigley, 2000), which uses emissions scenarios for greenhouse gases, reactive gases and sulphur dioxide, to calculate projected global warming for the eight SRES emissions scenarios.

For each emissions scenario, the IPCC provides low, moderate and high warming responses (equivalent to the 10th, 50th and 90th percentile projections) representing the range of sensitivity of global temperature rise to each emissions scenario.

4.3 Calculation of 'change factors'

The calculation of 'change factors' for individual GCMs is relatively straight forward.

CSIRO employ a 'pattern scaling' approach, as used in OzClim (described briefly below), to calculate, for each surface grid-point[5] of a GCM, the projected change (over the 21st Century) in a given climate variable per degree global warming. This is termed the 'pattern of change'. Patterns of change differ according to specific emissions scenarios, climate warming sensitivities and GCM runs.

Whereas temperature change per degree global warming is expressed in absolute terms, (i.e. degrees Celsius change per degree global warming), projected change in other climate variables (e.g. rainfall, evaporation, solar radiation and vapour pressure) is expressed in relative terms (i.e. as percentage change per degree global warming). To produce a 'change factor', the pattern of change (i.e. projected change per degree global warming) for a given climate variable is then multiplied by the warming curve from each of the eight SRES scenarios and climate warming sensitivities established using MAGICC. This 'change factor' can then be applied to a suitable 20th Century baseline climatology to produce projections of a given climate element.

The patterns of change used in the Consistent Climate Scenarios project have been obtained from OzClim patterns of change files and raw GCM files, provided by CSIRO Marine and Atmospheric Research (CMAR). The source files for the patterns of change computations are monthly averages of GCM derived model output for individual climate variables and for specific runs.

Further detail, on the use of patterns of change, to calculate estimates for specified climate variables at a particular point in the future, is described in detail in several papers (Mitchell, *et al.* (1999), Mitchell (2003), Whetton*, et al*. (2005) and Ricketts (2009)).

The pattern scaling approach employed by CSIRO (2010), and adopted for use in this project, can be summarised as follows:

[5] A GCM grid-point (which is typically 150-250km^2) is the essentially the same as a grid-'cell'.

Using output from individual runs of a given GCM forced by a specific emissions scenario:

Step 1

Extract global annual averages of 21st Century surface temperature projections (Figure 4.1a).

Step 2
For an individual GCM model's grid-point (typically 150-250km^2), extract monthly projections of a given climate variable (e.g. temperature or rainfall, Figure 4.1b).

Step 3

Using a simple linear regression approach, compute the linear trend (slope) between the global annual average surface temperature (Step 1) and the average monthly values of a given climate variable for that grid-point (Step 2). The calculated slope for each grid-point represents the mean rate of change of that climate variable per degree global warming' (Figure 4.1c).

Step 4

Repeat the above steps for each grid-point across Australia to produce the projected pattern of change per degree of 21st Century global warming across Australia for that climate variable (Figure 4.1d).

Step 5

As GCMs vary in their spatial resolution, interpolate the pattern of change obtained in Step 4 to a finer (regional) scale. It should be noted that representing GCM output on a common 25km x 25km base provides utility in terms of application but does not imply increased accuracy over the native resolution of the GCM outputs. [Patterns of change for specific locations are available in the monthly multiplier ancillary files supplied with CF data].

Step 6

Calculate 'change factors', by applying the above 'pattern of change' (change per degree global warming) to global warming projections (from MAGICC) for each of the eight SRES emissions scenarios (that part of the equation shown in brackets in Figure 4.2).

Step 7

Apply 'change factors' for specific locations to a suitable 20th Century baseline climatology to produce projections for a given climate variable (Figure 4.2). In OzClim, 'change factors' are applied to a 1975 to 2004 baseline climate (CSIRO, 2010).

Monthly climate 'change factors' for individual locations have been calculated for seventeen individual GCMs (see Section 6) using amounts of global warming at 2030 and 2050 for eight emissions scenarios (A1FI, A1B, A1T, A2, B1, B2, C02-450 and C02-550) and three climate warming sensitivities (low, median and high). The

'patterns of change' and amounts of global warming (from which the climate 'change factors' can be calculated) are contained in the monthly multiplier files (described in Section 3.1) provided with the projections data.

Further details related to the method used to produce OzClim patterns of change are available at: http://www.csiro.au/ozclim and documented by Mitchell *et al*. 1999; Page and Jones 2001, Michell 2003; Whetton *et al.* 2005; Ricketts 2009, and Ricketts and Page 2007.

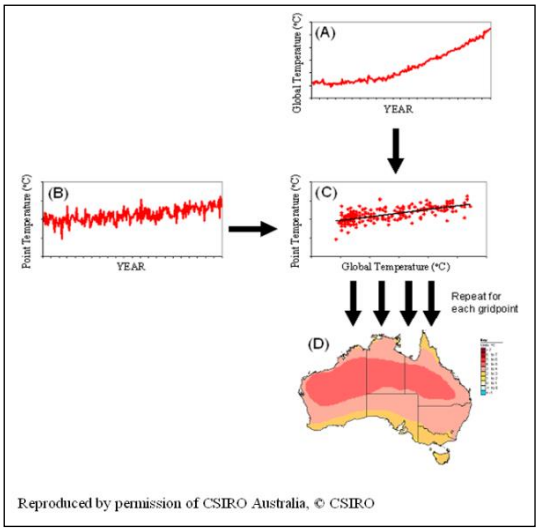


Figure 4.1 Steps to producing OzClim patterns of change for an individual month and single Global Climate Model (GCM). Panel A is the annual global temperature for the GCM. Panel B is the monthly temperature time-series for an individual grid-point. Panel C is the combination of Panel A and Panel B *(with a regression line from which the annual rate of change per degree of global warming (slope) for that month is calculated for a specific grid-point).* Panel D displays the slope for each grid-point across Australia, *following interpolation to a finer scale across Australia* (after CSIRO, 2010).

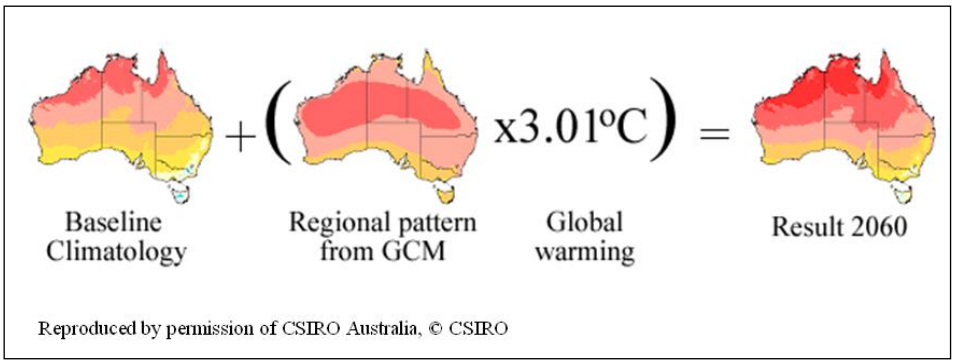


Figure 4.2 Climate scenario generation for annual temperature in 2060. The regional pattern from a GCM is multiplied by the global warming for 2060 and added to the observed baseline climatology (i.e. OzClim has used 1975-2004). In this example, the GCM is CSIRO Mk3.0, the emissions scenario is SRES A1FI, and the rate of global warming is high (after CSIRO, 2010).

Further information, about issues related in the calculation of 'change factors', including downscaling from Global Climate Models and the calculation of trends per degree of global warming, is discussed in Section 9 and 10.

4.4 A worked example – projecting climate data for 2050 for a specific location

An outline of the above processes, required to generate CCSP data based on the OzClim 'change factor' approach, is presented in Table 4.1. This example shows the steps required to calculate 2050 projections data for July at Brian Pastures, using the CSIRO-Mk3.5 GCM forced by the A1T emissions scenario with low climate warming sensitivity.

Table 4.1 An outline of the steps involved, to calculate 'change factors' for applying to a baseline climatology, to produce 2050 climate projections for July at Brian Pastures. This example uses CSIRO-Mk3.5 forced by the A1T emissions scenario with low climate warming sensitivity.

Step 1

- Extract 21st Century GCM projections of global annual average surface temperature from a selected Global Climate Model (i.e. CSIRO-Mk3.5).

Step 2

- Select climate variable (i.e. rainfall or temperature) and month (July).
- Extract the 21st Century projections (average monthly values) of climate variable at GCM model grid-point.
- Climate variable infilled by DSITIA, if not available through OzClim.

Step 3

- Compute linear trend (mean rate of change per degree of 21st Century global warming) between projections of global annual average surface temperature and projections of monthly climate variable at GCM grid-point level.

Step 4

- Repeat the above steps for each grid-point across Australia to produce the pattern of change (mean rate) per degree of 21st Century global warming across Australia for specific climate variables.

Step 5

- Interpolate regional 'pattern of change' to a uniform (25km x 25km) base, then select pattern of change for a specific location.
- In this example, at Brian Pastures (Location Code 040428), the CSIRO-Mk3.5 pattern of change for rainfall per degree of 21st Century global warming (obtained from the multiplier file, see Section 3.1) is -18.68%, and the pattern of change for minimum temperature per degree of global warming is +1.12ºC.

Step 6

- **Calculate climate 'change factor'** by multiplying the above 'pattern of change' by the projected amount of global warming at 2050.
- The amount of global warming, from MAGGIC, for 2050 using the A1T emissions scenario with low climate warming sensitivity is +1.24ºC (obtained from the multiplier file, see Section 3.1).
- For rainfall, the 2050 'change factor' (1.24 x -18.68) is **-23.16,** i.e. a 23.16% decrease.
- For temperature, the 2050 'change factor' (1.24 x 1.12) is **1.39**, i.e. a 1.39ºC increase.

Step 7

- Apply clamping if the 'change factor' is outside the acceptable range.
- Apply the 'change factors' to suitable 20th Century baseline climatology to produce projections for the given climate variables.
- In this example, for rainfall we take 23.16% off all SILO historical July daily rainfall values to obtain projected data for 2050.
- For temperature, we add 1.39ºC to all SILO historical July daily minimum temperature values to obtain projected data for 2050.

5 'Quantile-matching' (QM) methodology

This section of the User Guide provides an outline of the methodology that DSITI has used to prepare QM climate projections data for 2030 and 2050. Further information describing the 'quantile-matching' approach is documented in Kokic *et al.* (2012) and Panjkov (2012).

The QM method produces projected daily data for the future by mapping historical cumulative distribution functions (CDFs), sourced from a 1957 to 2010 training period, to a supposed future CDF. A variation in the QM method is used, depending on whether projections for 2030 or 2050 are required. Different methods are required, as there is almost no daily data for GCMs around 2030. In addition, even where data do exist, no daily data for surface water vapour and solar radiation are available.

For 2030, the future CDF is estimated by the forward projection of historical trends in monthly quantiles out to that year. However, beyond 2030, there is a risk that historically-based quantile trends may meet or cross each other at some point in time, particularly under emissions scenarios associated with high climate sensitivity to global warming. Therefore, to acquire 2050 projections datasets, future CDFs for rainfall and temperature variables have been computed differently, using daily data obtained from GCMs instead of extrapolating historical quantile trends.

As with CF data, QM 2030 projections have been computed for 19 GCMs, eight emissions scenarios, three climate sensitivities and six climate variables. However, due to limited daily GCM data, QM 2050 projections have only been prepared for a single GCM (ECHAM 5), emissions scenario (A1B) and climate sensitivity (median).

While the approach for 2050 rainfall and temperature projections uses daily GCM data, QM 2050 projections for other climate variables use the QM 2030 method extended to 2050 (discussed further in Section 5.2).

5.1 Steps involved to calculate QM projections data for 2030

Step 1

Compute the quantile ranking of a climate variable for each historical day in its containing month, based on a 1957 to 2010 training period.

Step 2

To construct a plausible future CDF (to represent future variability), project the historical trends in three or more "pivot" quantiles (usually 0.1, 0.5 and 0.9) out to the target projection year (usually 2030). These historical trends (Figure 5.1) are not used if their computed statistical significance exceeds a cut-off threshold, currently p-statistic = 0.1. Interpolation and use of conservative extrapolation methods has been used to estimate the future CDF at quantiles other than the pivot quantiles. This process is carried out for most[6] of the climate variables, but some of the climate variables will have been pre-transformed to limit any non-physical projections, such

[6] Pan evaporation is not computed by 'Quantile-matching', but uses the 'Change factor' methodology based on synthetic pan evaporation functions (Rayner, 2005) using 'Change factors' for vapour pressure and solar radiation.

as negative rainfall or solar radiation in excess of extraterrestrial incoming radiation. The pre-transformation is also done to normalise the data, i.e. make the regression residuals more nearly normally distributed. The QM procedure is applied to the transformed variables. An inverse transform is applied to the resulting projected data to generate the projected climate variables.

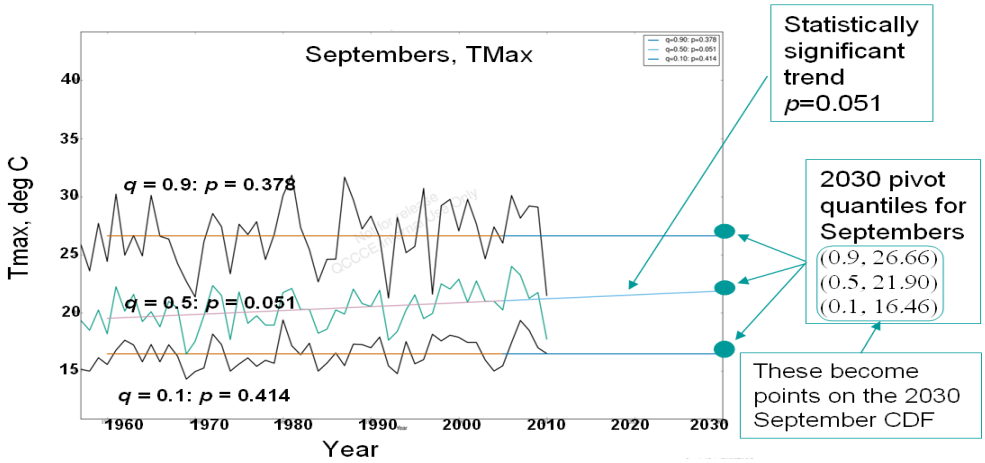


Figure 5.1 Quantile trend plot for September daily maximum temperature, showing how quantiles 0.1,0.5 and 0.9 are computed for 2030.

Step 3

Each historical value is replaced by a value from the future CDF with the same quantile rank, using 'quantile-matching' functions that have been computed for each location, month and climate variable (Figure 5.2). Projected values in the lower (upper) end of the target distribution (i.e. beyond pivot quantile 0.1 (0.9)), are based on the same shift that has been applied to the 0.1 (0.9) quantile.

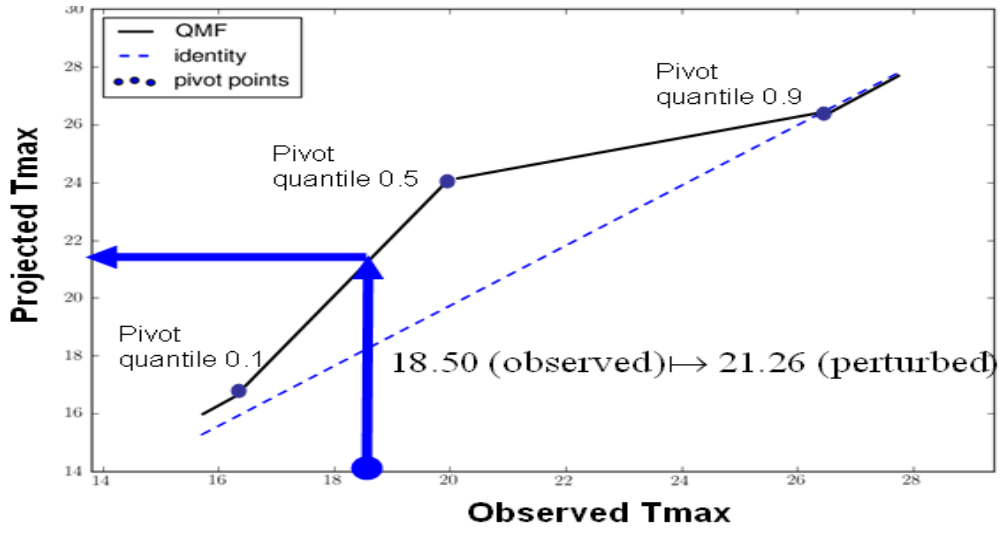


Figure 5. 2 Example of a 'quantile-matching' function for a specific month for daily maximum temperature, showing the target CDF for 2030 (black line).

Step 4

Historical climate variability is projected forward by computing quantile trend residuals (interpolated about the pivot quantiles), and applying these to the projected data by a second QM procedure (Figure 5.3). Without this step, there is too little inter-annual variation in the projected time series.

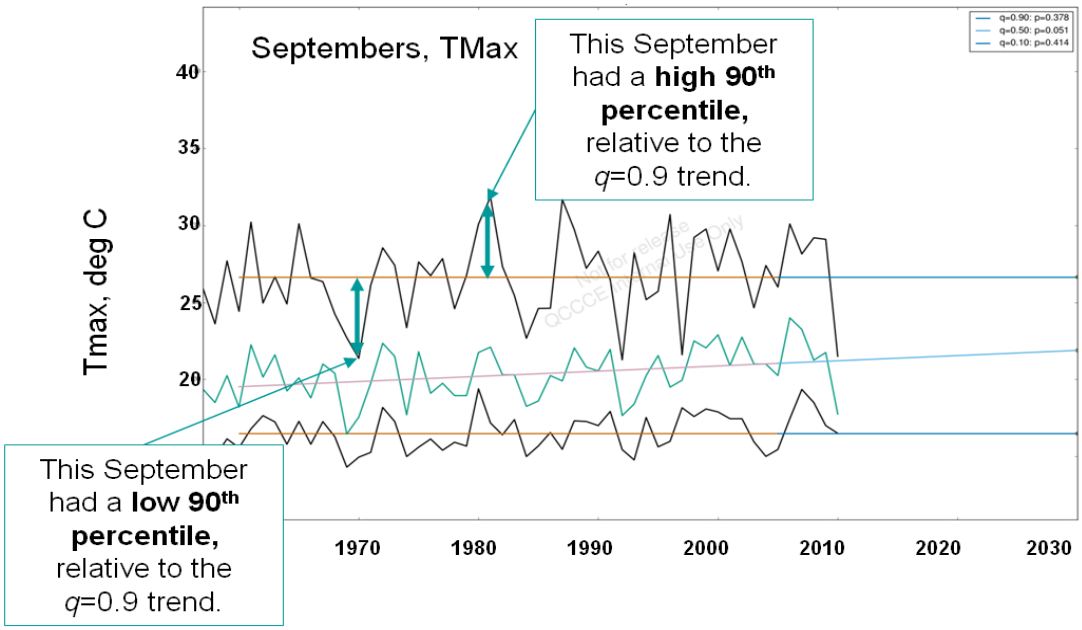


Figure 5. 3 Quantile trend plot for September daily maximum temperature, showing residuals. The projected data are adjusted by the residuals using a second qauntile matching pass.

Step 5

Lastly, the entire projected data stream is renormalised to conform to the mean value indicated by the OzClim trend coefficient ('change factor') associated with a specific GCM/emissions scenario/climate warming sensitivity. The resulting QM output should honour the mean implied by the GCM and (approximately) the spread of values implied by the new target CDF.

5.2 Variation of methodology for calculating 2050 QM projections data

As discussed, to acquire 2050 projections datasets, future CDFs for rainfall and temperature variables have been computed using daily data obtained directly from GCMs, rather than by extrapolating historical quantile trends.

Step 1

To start with, pivot quantiles for 2050 for rainfall, maximum and minimum temperature are computed and saved for each point in the GCM data grid. This grid of GCM derived 2050 pivot quantiles is then interpolated using bilinear interpolation so that pivot quantiles can be obtained for each station location.

Step 2

The 2050 CDF is then computed from the station-specific pivot quantiles and interpolation and conservative extrapolation methods are applied so that the 2050 CDF can be estimated at other quantiles besides the pivot quantiles. This interpolation process is carried out for most of the climate variables, but some of the climate variables will have been pre-transformed to limit any non-physical projections, such as negative rainfall. The pre-transformation is also done to normalise the data (i.e. make the regression residuals more nearly normally distributed). The QM procedure is applied to the transformed rainfall and temperature variables. An inverse transform is applied to the resulting projected data to generate the projected climate variables.

After this, steps 3 to 5 are applied, as per the 2030 QM method.

Caution

- *The QM 2050 projections data should be used with care, as these projections are only available for a single GCM (ECHAM 5), emissions scenario (A1B) and climate sensitivity (median).*
- *QM 2050 projections are limited to the ECHAM 5 GCM. Of the 17 GCMs used in this project (i.e. CF and QM 2030 projections), ECHAM 5 is the only GCM that is both noted by the Expert Panel as being more likely to produce credible projections and having a complete set of raw daily rainfall, maximum and minimum temperature data available from 1900 to 2100, particularly 15 years either side of 2050.*
- *Users should note that QM 2050 projections are currently limited to the A1B emissions scenario, which, while being recommended for use, does not represent the most extreme risk.*
- *Furthermore, while QM 2050 projections for daily rainfall, maximum and minimum temperature projections are sourced from daily GCM data, other daily climate variables were not available in GCMs, due to limited holdings of daily data around 2050.*
- *Placeholder columns in the QM 2050 .met files for the missing vapour pressure, pan evaporation and solar radiation have been infilled with projections data for 2050 based on the QM 2030 methodology, using extrapolation of historical quantile trends to 2050, with renormalisation to the GCM mean by using 'change factors' with median sensitivity to global warming. The QM 2050 pan evaporation has been computed using Rayner (2005) synthetic pan evaporation functions, using vapour pressure as an input.*

5.3 Post-projection clamping

The projection method can result in occasional non-physical values (i.e. values that will not occur in reality), such as negative rainfalls, evaporations or vapour pressures, or radiation data that exceed incoming solar radiation. The occurrence of such non-physical values is reduced by pre-transforming the data, but some non-physical values may still occur. Where such data occurs, it is corrected by a brute-force clamping back to the physical range. In the QM datasets, currently supplied, such values are rare. In the prototype data, most of the 312 variables/stations showed no

clamping. Of the 35 variables/stations that required clamping, the number of clamped values was less than 87 in 19723 days (<0.4%), apart from four cases where the counts were 115 (0.58%), 255 (1.3%), 146 (0.74%) and (2.6%).

5.4 Transforms applied

Some climate variables are transformed before applying the 'quantile-matched' projection. The currently used transforms (and their inverses) are provisional only, and may be later changed.

Maximum and minimum temperature

No transforms.

Evaporation

Evaporation is computed using synthetic pan evaporation formulae (described in Rayner, 2005) and no transforms have been applied. However, clamping is applied, after having 'quantile-matched' the projection, to ensure that evaporation values are not negative.

Rainfall

Only positive rainfall data are projected. Positive rainfall data are transformed by taking the cube root. The immediate goal is to reduce the leverage of the high rainfall events in the regressions. Post-projected data is then back-transformed to rainfall by cubing. This is followed by a procedure which is consistent with the CF based projections clamping algorithm, to ensure that all rainfalls are positive.

Vapour Pressure

Vapour pressure (VP) has been transformed to specific humidity (SH) using WMO 2008 formulae and then transformed back to VP post-projection. The immediate goal is to reduce the spread of data to decrease leverage of any outliers. A final clamping, post-projection, occurs to ensure that vapour pressures are strictly positive. The lower cut-off is arbitrarily chosen as the saturation VP at the lowest recorded temperature in the Australian observed record (-23.0ºC, 29 June 1994, Charlotte Pass, NSW).

Solar radiation

Solar radiation is first scaled by the extra-terrestrial incoming radiation, to produce a ground level proportion of extra-terrestrial radiation between 0 and 1 inclusive. This proportion is transformed by the logit transform to allow values to range over negative infinity to positive infinity. The post-projected data is back-transformed by the inverse of the logit function, the logistic function. The goal of these transforms is to confine the projected proportional data to the [0,1] interval, with the main effect at the high and low end of the range. The proportion data is then restored to unscaled solar radiation data. No clamping is needed as the transform/projection/back-transform sequence is guaranteed to return values in the physical range.

6 Description of daily climate variables

6.1 SILO data

The SILO historical data sets, to which the OzClim[7] scaling approach has been applied to produce the 2030 and 2050 projections data, include the following six daily climate variables, useful for biological modelling:

- Rainfall (mm), for the 24 hours to 9am on the date listed
- Maximum air temperature (ºC), for the 24 hours from 9am on the date listed
- Minimum air temperature (ºC), for the 24 hours to 9am on the date listed
- Solar radiation (megajoules per square metre), on the date listed
- Vapour pressure (hectopascals), at 9am on the date listed
- Pan evaporation (mm), for the 24 hours from 9am on the date listed

While rainfall is captured in standard 203 mm (eight inch) diameter gauges at the majority of Australian recording sites, some sites have automated gauges. A standard rain gauge can hold 300 mm of water before overflowing. Accumulated rainfall totals (i.e. for periods of more than a day) are not included in the SILO patched point datasets, unless they have already been apportioned.

Maximum and minimum air temperatures are measured using thermometers or electronic temperature sensors. The instruments, which are standardised at 1.3 metres above level ground, are located inside a Stevenson screen or other standard enclosure (to protect them from exposure to direct sunlight). As with rainfall, SILO does not include accumulated maximum or minimum temperatures in its patched point data sets, unless they have been apportioned.

Solar radiation is radiant energy emitted by the sun. The measured data is the combined total of both direct and diffuse solar radiation, per day, received on a horizontal surface.

Vapour pressure is the partial pressure exerted by the water in the atmosphere. The vapour pressure is dependant on the dry bulb air temperature and the coincident relative humidity.

Pan evaporation, which integrates the evaporative effects of temperature, humidity, solar radiation and wind, is normally highest when it is hot, windy and dry. Pan evaporation is measured using a Bureau of Meteorology ‘Class A’ evaporimeter, which is a water-filled circular pan of galvanized iron, 121 cm in diameter and 25 cm deep, mounted on an open wooden platform. Manually observed Bureau of Meteorology Class A pan evaporation site data are used in the SILO historical data files (i.e. APSIM and p51 formats) from 1970 to current. It is worth noting that bird cages were installed in the early 1970s to reduce errors (e.g. evaporation readings were occasionally too high, due to animals drinking or splashing water). Prior to 1970, the SILO historical pan evaporation data have been interpolated from long term averages.

[7] OzClim version 3

Notes

- *The accuracy of the historical daily data depends on many factors, including date, location and how the climate variable has been measured.*
- *Although SILO data is supplied to one decimal place to maintain consistency, in some cases it may not be accurate to that precision (i.e. an observer measuring the temperature to the nearest 0.5ºC).*
- *All SILO historical data are provided by the Australian Bureau of Meteorology and are collected and are prepared to their standards.*

6.2 Patched Point and drilled data

The SILO historical datasets are available as either ‘Patched Point’ or ‘Drilled’. While both datasets provide continuous daily climate data, suitable for use in simulation models, there are subtle but important differences between the two sets.

Patched Point data uses original Bureau of Meteorology measurements for a particular meteorological station, but with interpolated data used to fill ("patch") any gaps in the observation record.

Drilled data is based on grids of data, derived by interpolating the Bureau of Meteorology's station records. Interpolations are calculated by splining and kriging techniques. The drilled data are all synthetic; there are no original meteorological station data left in the calculated grid fields. However, the drilled data does have the advantage of being available for any set of coordinates in Australia.

The Patched Point data would typically be used when an analysis or simulation is needed quite close to a meteorological station. However, if an analysis is required for a location which has no meteorological station nearby, then the drilled data is the more relevant product. Drilled data sets can be processed when a specific latitude and longitude is provided.

7 Emissions scenarios and climate warming sensitivity

Available CF data includes 2030 and 2050 climate projections data, based on nineteen GCMs for approximately 4700 Australian patched-point climate stations. To better inform users about the projections datasets and assist in dataset selection, this section provides users with some background information about emissions scenarios and associated climate warming sensitivity, including brief recommendations.

7.1 Emissions scenarios - background information

Economic development, demographic and technological change play critical roles in the outcome of future greenhouse gas emissions and potentially climate change. As such, the IPCC documented a range of greenhouse gas emissions scenarios for the future (used in both AR3 and AR4 modelling) in their 'Special Report on Emissions Scenarios (SRES)' (IPCC, 2000). The emissions scenarios are grouped into four categories termed 'families' (A1, A2, B1 and B2) each family having a storyline based on specific socio-economic and environmental characteristics.

The six IPCC AR4 emissions scenarios considered in the Consistent Climate Scenarios Project are described in Table 7.1. Additional to the six A and B family SRES emissions scenarios, this project considers two CO_2 'stabilisation scenarios', based on the work of Wigley *et al*. (1996), listed in Table 7.2. Projections to 2100 for all eight scenarios are presented in Figure 7.1.

Table 7.1 IPCC AR4 SRES emissions scenarios used in the Consistent Climate Scenarios Project (adapted from IPCC, 2000).

	SRES Emissions Scenario	***Remarks***	***Storyline***	***Energy use***	***Median of projected CO_2 concentrations, ppm***	
					2030	***2050***
Recommended	**A1FI**	**Most recommended** Represents the most extreme global warming risk analysed to date. Observations suggest A1FI most closely represents the current trend in global CO_2 emissions. Only a few runs have been made. Not available through PCMDI. Data obtained by pattern-scaling.	Very rapid economic growth. Global population that peaks around 2050 and declines thereafter. Rapid introduction of new and more efficient technologies.	Fossil intensive	449 Same value as RCP8.5 (AR5)	555 Slightly higher than RCP 8.5 (541ppm)
	A1B	This model has the most variables. Submitted to IPCC for PCMDI. Data obtained by pattern-scaling.		Balance across all sources	447	522
	A1T	Not available through PCMDI. Data obtained by pattern-scaling.		Emphasis on non-fossil sources	435 Same value as RCP4.5	496
	A2	**Preferred alternative to A1FI.** Similar to A1FI for the early 21st Century. Submitted to IPCC for PCMDI, but not as complete as A1B. Data obtained by pattern-scaling.	Self-reliance and preservation of local identities. Continuously increasing global population. Economic development regionally oriented. Per capita economic growth and technological change more fragmented and slower than for other storylines.		444	522
Looking increasingly unlikely	**B1**	Not available through PCMDI. Data obtained by pattern-scaling.	A convergent world with the same global population that peaks around 2050 and declines thereafter. Rapid changes in economic structures toward a service and information economy, with reductions in material intensity. Emphasis on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.	Introduction of clean and resource-efficient Technologies	432	482
	B2	Submitted to IPCC for PCMDI, but not as complete as A1B. Data obtained by pattern-scaling.	Emphasis on local solutions to economic, social, and environmental sustainability. Continuously increasing global population (rate lower than A2). Intermediate levels of economic development and less rapid and more diverse technological change than B1 and A1 storylines. Oriented toward environmental protection and social equity, but focused on local and regional levels.		425	473

Further reading and details regarding the full range of greenhouse gas emissions scenarios is available at: http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf .

Table 7.2 CO_2-stabilisation scenarios used in the Consistent Climate Scenarios Project (adapted from IPCC, 2000).

CO_2-stabilisation scenario	***Storyline***	***Remarks***
CO2-450	CO_2 emissions increase and then stabilise by 2100 (a 'very low' emissions scenario).	Data for this project obtained by pattern-scaling.
CO2-550	CO_2 emissions increase and then stabilise by 2150 (similar to B1).	

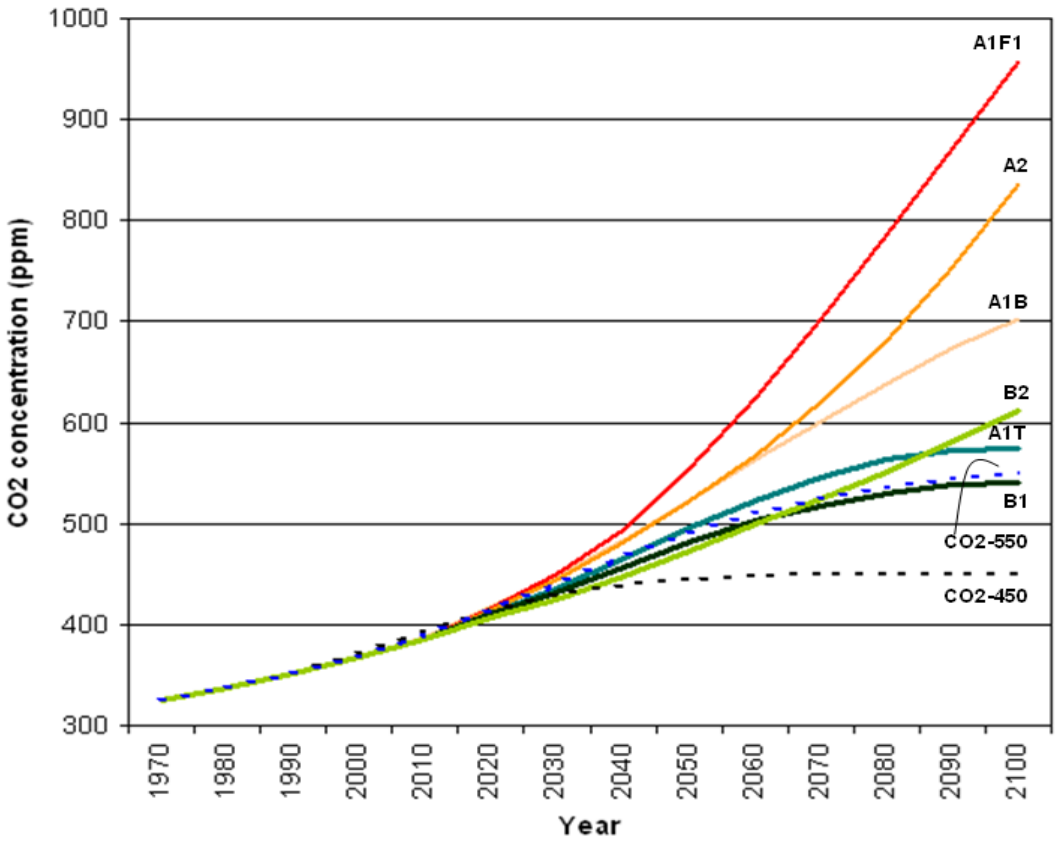


Figure 7.1 Historical and projected CO_2 concentrations for the emissions scenarios used in the CCSP (data source: http://www.ipcc-data.org/ancilliary/tar-bern.txt).

For all GCMs, the experiments in the CMIP3 database do not cover the full range of emissions scenarios which were considered by the IPCC in its Special Report on Emissions Scenarios (SRES). The suite of model runs in CMIP3 are forced by a limited number of SRES emissions scenarios including SRES A1B, a slightly smaller set from SRES A2, and a still smaller set from SRES B1. The A1FI high emissions scenario which is increasingly being adopted in policy development was not run for CMIP3. The experiments also did not include a desirable level of replication.

The IPCC employed a relatively straight-forward methodology to extrapolate AR4 model outputs across all SRES scenarios and to quantify the sensitivity of the warming response to a particular emissions scenario. This method involved calculating projected global warming for the eight SRES emissions scenarios using a single climate model (MAGICC). For each emissions scenario, the IPCC provides three warming responses (low, moderate and high) representing the range of sensitivity of global temperature rise to each emissions scenario. These are discussed in the following section.

7.2 Selecting emissions scenarios

Although the 21st Century concentration pathways for the six emissions scenarios and two CO_2-stabilisation scenarios described remain uncertain, we strongly recommend the use of A1FI, since recent observations show that A1FI (which carries the most extreme risk) is the emissions scenario that most closely represents the present-day situation. A1FI depicts a socio-economic future of very rapid economic growth and rapid introduction of new and more efficient technologies. The A2 emissions scenario is often preferred as an alternative to A1FI.

The low-end 'B' family of SRES emissions may be overly optimistic. Inclusion of low-end scenarios in modelling the range of uncertainties for climate change projections has the potential to bias final output and hence under-estimate the effects of climate change.

Thus, the use of mid to high-end 'A' family of SRES emissions scenarios, which produce higher rates of global warming, is recommended as being more realistic than using those from the low-end, low rate of global warming, 'B' family of emissions scenarios (Table 5.1).

Further reading, about limitations in emissions scenarios, is presented in Section 10.3.

7.3 Climate warming sensitivity

Climate warming sensitivity is a simple but useful measure of the strength of the effect of CO_2 concentrations on climate, particularly global temperature.

Rahmstorf (2008) noted that a doubling of CO_2, from the pre-industrial 280 ppm to the 560 ppm estimate for the mid-to-late 21st Century (the classic IPCC range), would lead to between 1.5°C and 4.5°C of global warming, but added that this range could now have narrowed to 2°C to 4°C. The US National Academies (2010) confirm a similar range (2.1°C to 4.4°C) with a best estimate of 3.2°C. The pre-industrial value refers to the period circa 1750 (IPCC, 2007). Ramsdorf (2008) also states that global

warming at a particular time depends on the time-history of past CO_2 (and other forcing) changes, not just anthropogenic climate change. As such, climate warming sensitivity may not be constant over time and is usually grouped into three ranges (low, median and high).

Climate warming sensitivities used for the projections data

The CF projections data provided in the Consistent Climate Scenarios Project utilise climate warming sensitivities (low, median and high) calculated from estimates of global warming, due to the effect of global CO_2 concentrations, at both 2030 and 2050. These climate warming sensitivities are provided for each of the six SRES emissions and two CO_2-stabilisation scenarios listed in Tables 7.1 and 7.2.

Note

- *These climate warming sensitivity options should not be confused with those provided on the OzClim website which refer to the emissions scenarios per se. That is, OzClim offers SRESscenarios B1, A1B and A1FI as low, medium and high warming sensitivity options respectively.*

To present this possible range of outcomes in a useful manner, the emissions projections were ranked and the 10th, 50th (median) and 90th percentile projections were chosen to represent, respectively, a low 'L', median 'M'' and high 'H' global warming sensitivity to a given emissions scenario.

The process used to select an amount of global warming from MAGICC is represented in Figure 7.2 and is as follows:

1) Select a scenario (e.g. SRES A1FI) – this yields a family of three curves.
2) Select a year of interest (e.g. 2050).
3) Select a climate warming sensitivity (low 'L', medium 'M', or high 'H').

In this particular example, the result for A1FI with high climate warming sensitivity is a single global warming offset of 2.35ºC'.

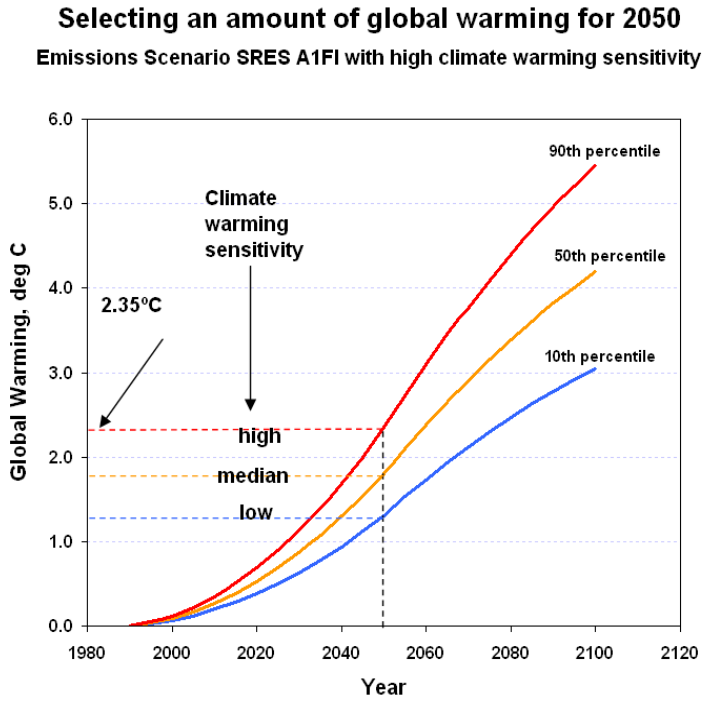


Figure 7.2 Selecting the amount of global warming for 2050.

Amounts of global warming for each of the eight emissions scenarios and the three climate warming sensitivities are presented in Table 7.3. These data are also available in the 'monthly multiplier' files supplied with the data.

Table 7.3 Projected amounts of global warming at 2030 and 2050 (change from a 1990 baseline, from MAGICC) for the eight emissions scenarios and three climate warming sensitivities utilised in producing CF 2030 and CF 2050 data.

Emissions scenarios and projected amounts of global warming (ºC) at 2030 and 2050, from MAGICC

	2030 Climate warming sensitivity (Change from 1990 baseline, ºC)			**2050** Climate warming sensitivity (Change from 1990 baseline, ºC)		
	Low	**Median**	**High**	**Low**	**Median**	**High**
Scenario	10th percentile	50th percentile	90th percentile	10th percentile	50th percentile	90th percentile
A1F1	0.63	0.87	1.13	1.31	1.81	2.35
A1B	0.66	0.90	1.17	1.12	1.53	1.99
A1T	0.73	1.00	1.30	1.24	1.71	2.22
A2	0.57	0.79	1.02	1.05	1.44	1.87
B1	0.54	0.74	0.96	0.82	1.13	1.47
B2	0.65	0.89	1.15	0.97	1.33	1.72
C02-450	0.52	0.71	0.89	0.83	1.15	1.43
C02-550	0.57	0.78	0.96	0.98	1.34	1.66

We recommend the combined use of all three climate warming sensitivities (low, median and high) as these sensitivity values will incorporate some of the uncertainty about the range of potential biosphere carbon feedbacks. These biosphere carbon feedbacks could be as large as the difference in the SRES scenarios.

Further reading, related to aspects of climate warming sensitivity, is available in Wigley (2000) as well as:

- https://wiki.csiro.au/confluence/display/ozclim/Science#Science-Development
- http://www.nap.edu/catalog/12877.html
- http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf
- http://en.wikipedia.org/wiki/Climate_sensitivity

8 Global Climate Models

To better inform users about the use of the CF datasets and dataset selection, this section provides users with brief background information about the range of Global Climate Models (GCMs) that we have used, including recommendations to assist users on GCM selection.

Table 8.1 indicates the full set of CMIP3 GCM model runs that were available to the CCSP to consider (including climate forcings and spatial resolution) of which 19 have been selected for use. The CSIRO-Mk3.5 GCM, hasn't been assessed with a rank, in terms of skill, by the CCSP Expert Review Panel. However, it is expected to be an improvement over CSIRO-Mk3.0. Detailed information on all available IPCC AR4 listed GCMs is documented on the PCMDI website at http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php.

Table 8.1 IPCC AR4 GCM characteristics, including their official PCMDI CMIP3 name, number of ensemble members, specific climate forcings, spatial resolution and rank as assessed by the Consistent Climate Scenarios Project Expert Panel.

GCM CHARACTERISTICS

			FORCINGS												MODEL RESOLUTION
Expert Panel Ranking	OzClim Name	Ensemble Members	Well-mixed greenhouse gases	Ozone	Sulphate direct	Sulphate indirect	Black carbon	Organic carbon	Mineral dust	Sea salt	Landuse	Solar irradiance	Volcanic aerosol	Number of forcings	Horizontal resolution (in degrees) and the number of vertical levels (L)
1	HADCM3	run1	+	+	+	+								4	3.75x2.5 L19
2	MIROC-H	run1	+	+	+		+	+	+	+	+	+	+	10	1.12x1.12 L56
3	GFDL-21	run1	+	+	+		+	+			+	+	+	8	2.5x2.0 L24
4	GFDL-20	run1	+	+	+		+	+			+	+	+	8	2.5x2.0 L24
5	MIROC-M	E2_3	+	+	+		+	+	+	+	+	+	+	10	2.8x2.8 L20
6	ECHO-G	E1_2_3	+		+	+								3	3.8x3.8 L19
7	HADGEM1	run1	+	+	+	+	+	+			+	+	+	9	1.9x1.25 L38
8	ECHAM5	E1_2_3	+	+	+	+								4	1.9x1.9 L31
9	MRI-GCM232	E1_2_3_4_5	+		+							+		3	2.8x2.8 L30
10	NCAR-CCSM	E1_2	+	+	+		+	+				+	+	7	1.4x1.4 L26
11	CCCMA-63	run1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	
12	GISS-AOM	E1_2	+		+					+				3	
13 (to be adjusted)	INMCM	run1	+		+			+						3	5.0x4.0 L21
14	CCCMA-47	run1	+		+									2	
15	IAP-FGOALS-G10	E1_2_3	+		+									2	2.8x2.8 L26
16	CSIRO-Mk30	run1	+	+	+									3	1.9x1.9 L18
17	CNRM	run1	+	+	+		+							4	2.8x2.8 L45
18	ISPL-CM4 (not used in project)	run1	+		+	+								3	
19	BCCR	run1	+		+									2	1.9x1.9 L31
20	GISS-ER (not used in project)	E2_4	+	+	+	+	+	+	+		+	+	+	10	
21	NCAR-PCM1 (not used in project)	run4	+	+	+							+	+	5	
22	GISS-EH (not used in project)	E1_2_3	+	+	+	+	+	+	+		+	+	+	10	
NOT ASSESSED	CSIRO-MK35	run1	+	+	+									3	1.9x1.9 L18

Yellow shading: models used in the Consistent Climate Scenarios Project

Note: The INMCM GCM is no longer recommended for use due to unstable drift in the model. The rank for this model will be adjusted.

The CCSP Expert Panel classified the available GCMs according to each model's reliability in the Australian region (Table 8.2; Crimp *et al*. 2010) based on Smith and Chiew (2009). Table 8.2 also compares this ranking with that of Suppiah *et al*. (2007). Similar rankings provided by other studies are shown in Table 8.4.

As a result, the panel recommended nineteen of these models for use in the preparation of CCSP projections data.

Table 8.2 Twenty-three GCMs categorised in terms of their overall performance in simulating climate variables, derived from an aggregate of global and regional statistics, adapted from Smith and Chiew (2009), Crimp *et al*. (2010) and Suppiah *et al*. (2007). The grey-shaded panels highlight both the Consistent Climate Scenarios Project Expert Review Panel and Suppiah's more-favoured models.

GCMs ***Name used in Consistent Climate Scenarios Project***	***PCMDI CMIP3 GCM name***	***Weighted failure rate (%) Smith and Chiew (2009)***	***Consistent Climate Scenario Project Expert Review Panel recommendation Crimp et al. (2010)***	***Demerit points based on Australian rainfall, temperature and MSLP (Suppiah et al. 2007)***
HADCM3	UKMO-HadCM3	0%	**More likely to produce credible projections**	6
MIROC-H	MIROC3.2(hires)	8%		7
GFDL-21	GFDL-CM2.1	13%		2
GFDL-20	GFDL-CM2.0	20%		2
MIROC-M	MIROC3.2(medres)	25%		7
ECHO-G	ECHO-G	33%		4
HADGEM1	UKMO-HadGEM1	33%		2
ECHAM5	ECHAM5/MPI-OM	38%		1
MRI-GCM232	MRI-CGCM2.3.2	40%	Likely to be less reliable	3
NCAR-CCSM	CCSM3	44%		2
CCCMA-63	CGCM3.1(T63)	50%		10
GISS-AOM	GISS-AOM	58%		8
INMCM	INM-CM3.0	59%	**Not recommended**	7
CCCMA-47	CGCM3.1(T47)	63%	Likely to be less reliable	8
IAP-FGOALS-G10	FGOALS-g1.0	63%		2
CSIRO-MK30	CSIRO-Mk3.0	73%	Consistently under performed	7
CNRM	CNRM-CM3	75%		4
Not used in project	IPSL-CM4	75%		14
BCCR	BCCR-BCM2.0	88%	**Not recommended**	5
Not used in project	GISS-ER	88%		8
Not used in project	PCM	89%		11
Not used in project	GISS-EH	100%		14
CSIRO-MK35	CSIRO-Mk3.5	Not assessed, but expected to be better than CSIRO-Mk3.0		

Note

- *The INMCM GCM, previously rated 'likely to be less reliable', is no longer recommended for use due to unstable drift in the model.*

The CF Version 1.0 projections data provided in September 2010 included projections data from only eight models for which infilling of any trend per degree of global warming data has been reasonably straight forward. By April 2011, projections data from nine additional GCMs had been progressively infilled enabling the

production of the CF Version 1.1 data. As at June 2012, the latest CF Version 1.2 and QM 2030 datasets are available from a total of nineteen GCMs.

Detail on the 'infilling' methodology is discussed in Section 9, with the infilling status for each model summarised in Table 9.10.

8.1 Selecting Global Climate Models

The issue of Global Climate Model (GCM) selection is an important one and various views exist as to the best approach to take. It is desirable that end-users can relate their results, based on their choice of GCMs, to the results from another user who has chosen a different set of GCMs - particularly if the results differ.

A DAFF-sponsored workshop was held in June 2011 where participants were asked to consider how to ensure comparability between projects, via use of GCMs linked to a common set of climate change scenarios. The workshop agreed that a common approach to selecting model projections should be one based on the work of Watterson (2011). Watterson's paper describes how projected Australian 21st Century rainfall responses cluster, for the range of CMIP3 GCMs, according to global warming sensitivity and East Indian verses West Pacific Ocean temperature responses. The rainfall responses, which can be split into four Representative Future Climate (RFC) partitions (Figure 8.1), are based on:

- **HI**: A high level of global warming, where the Eastern Indian Ocean warms faster than the Western Pacific Ocean.
- **HP**: A high level of global warming, where the Western Pacific Ocean warms faster than Eastern Indian Ocean.
- **WI**: A low level of global warming, where the Eastern Indian Ocean warms fasters than Western Pacific Ocean.
- **WP**: A low level of global warming, where the Western Pacific Ocean warms fasters than Eastern Indian Ocean.

Considering the above, a mean 21st Century climate response (for rainfall and other climate variables), has been derived for the CCS project, by compositing modelled data (based on selected GCMs) within each of Watterson's four RFC partitions (Figures 8.1, 8.2 and 8.3). The groups of GCMs that are being used to produce 'CCS Composite' climate projections data for each RFC are listed in Table 8.3.

While the CCS Expert Panel has recommended use of the complete set of 19 GCMs that are available in CCS for climate projections analysis, the use of data based on the mean RFC related climate response patterns (HI, HP, WI and WP) has been offered as a secondary option where this is not practicable. In cases where single GCMs are selected, the selection of at least one GCM from each RFC partition will provide coverage of a range of possible outcomes.

DSITI, the Expert Panel and DAFF see the use of projections data based on these RFC related climate response patterns as an important step in ensuring comparability between projects.

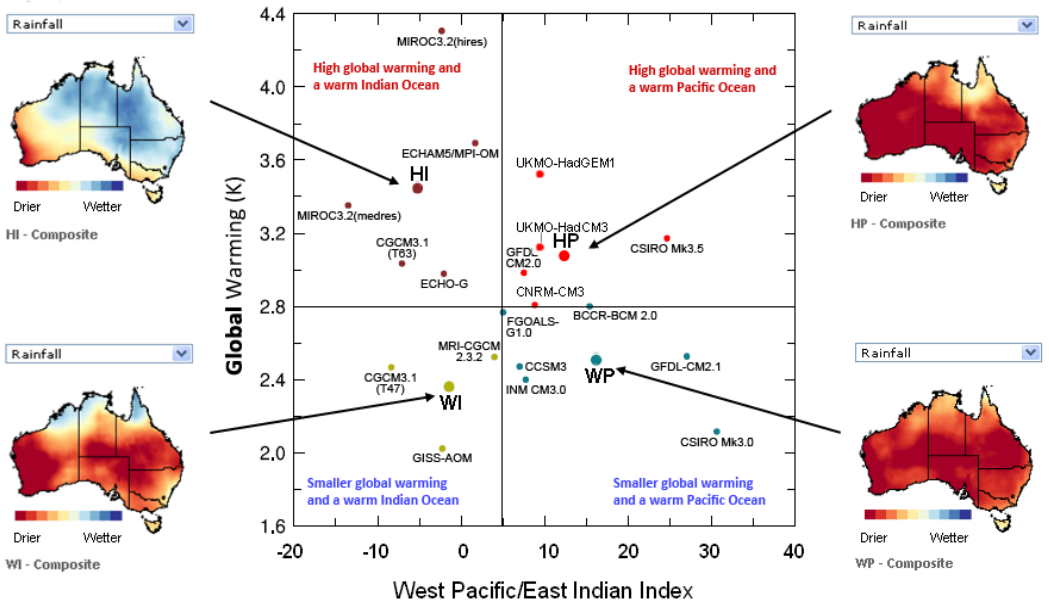


Figure 8.1 A partition of CMIP3 Global Climate Models (GCMs) for future climate using global warming sensitivity and ocean warming indices (adapted from Watterson, 2011). Values for nineteen individual GCMs (forced by the SRES A1B emissions scenario) are represented by the small dots and labelled by their GCM model code (Table 8.2). The central horizontal and vertical lines separate the four Representative Future Climate (RFC) partitions. The larger dots indicate the CCS composite means for GCMs within each of the four RFC responses: (HI) high global warming and a warmer Indian Ocean; (HP) high global warming and a warmer Pacific Ocean; (WI) lower global warming and a warmer Indian Ocean and; (WP) lower global warming and a warmer Pacific Ocean. The maps show projected 21st Century changes in rainfall for the GCMs clustered in each of the four (HI, HP, WI and WP) RFC partitions.

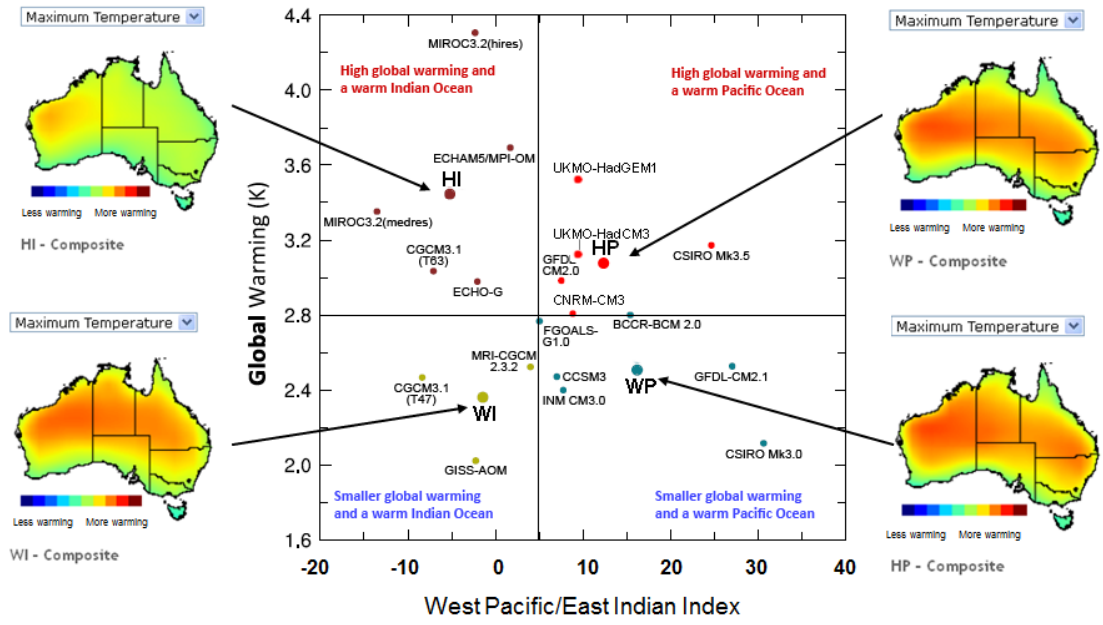


Figure 8.2 The maps show projected 21st Century changes in maximum temperature for the GCMs clustered in each of the four (HI, HP, WI and WP) RFC partitions.

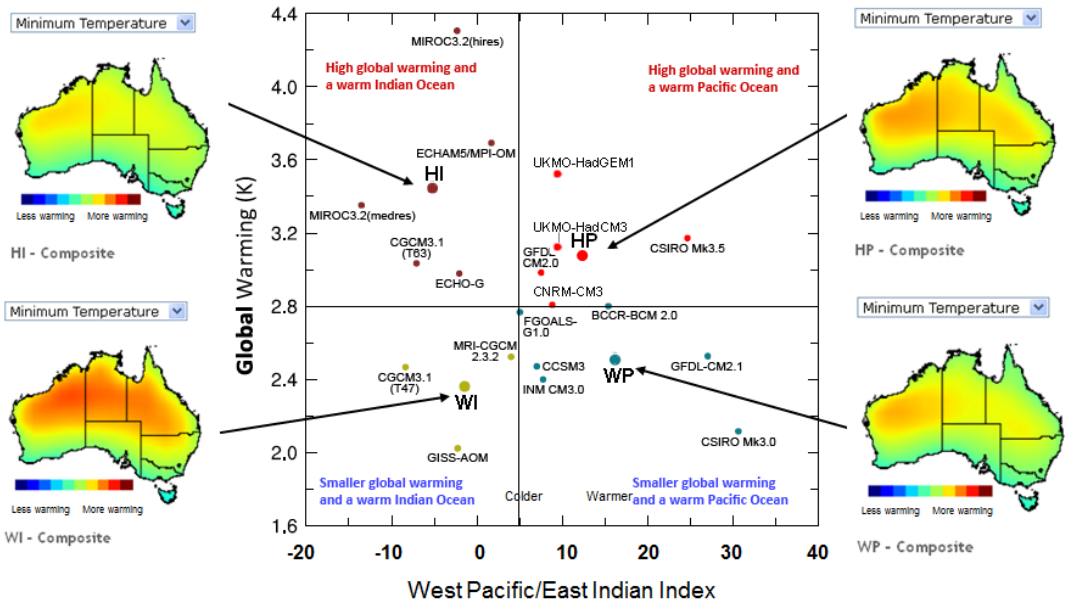


Figure 8.3 Projected 21st Century changes in minimum temperature for the GCMs clustered in each of the four (HI, HP, WI and WP) RFC partitions.

Table 8.3 Representative Future Climate partitions (RFC) and associated GCMs

Representative Future Climate partition (RFC).	GCM name used in Consistent Climate Scenarios Project	PCMDI CMIP3 name	Expert Review Panel recommendation
HI	CCCMA-63	CGCM3.1(T63)	Likely to be less reliable
	ECHAM5	ECHAM5/MPI-OM	More likely to produce credible projections
	ECHO-G	ECHO-G	
	MIROC-H	MIROC3.2(hires)	
	MIROC-M	MIROC3.2(medres)	
HP	CNRM	CNRM-CM3	Consistently under performed
	CSIRO-MK35	CSIRO-Mk3.5	Not assessed, but expected to be better than CSIRO-Mk3.0
	GFDL-20	GFDL-CM2.0	More likely to produce credible projections
	HADCM3 *	UKMO-HadCM3	
	HADGEM1*	UKMO-HadGEM1	
WI	CCCMA-47	CGCM3.1(T47)	Likely to be less reliable
	GISS-AOM	GISS-AOM	
	MRI-GCM 232	MRI-CGCM2.3.2	
WP	BCCR	BCCR-BCM2.0	Not recommended
	CSIRO-MK30	CSIRO-Mk3.0	Consistently under performed
	GFDL-21	GFDL-CM2.1	More likely to produce credible projections
	IAP-FGOALS-G10	FGOALS-g1.0	Likely to be less reliable
	INMCM	INM-CM3.0	Not recommended
	NCAR-CCSM	CCSM3	Likely to be less reliable

** UK Met Office Hadley Centre models added in June 2012*

8.2 Composite (HI, HP, WI and WP) climate projections data

It is well known that individual GCMs are subject to individual model bias. For this reason the CCS Expert Panel recommends either: 1) running the 19 GCMs supplied, or 2) if this is not practicable, short-cutting this processing by ordering composite data based on RFCs.

Composite daily climate projections data for 2030 and 2050 can be ordered for each of the four RFCs (HI, HP, WI and WP) through the CCS web-portal (see Appendix, Data Order Step 3). In addition, for each RFC, the multiplier files (Section 3.1) that are provided list monthly and annual projected rates of change per degree of 21st Century global warming for a range of climate variables.

Notes

- *Before running composite projections, it may help to become familiar with the 'Plots of simulated 20th and 21st Century climate' provided in this project. These plots have been provided for individual runs of all 19 GCMs, used in the CCS project, based on the A1B emissions scenario for Australian continental area weighted rainfall and mean temperature and are discussed in Section 3.8 of the User Guide.*
- *Users should note that the partitioning approach described by Watterson (2011), is focused on annual climate change over the whole of the 21st Century, nominally for 2100 relative to 2000 using 23 CMIP3 GCMs forced by the SRES A1B emissions scenario, for which the best estimate for global warming was an increase of 2.8ºC. The Consistent Climate Scenarios projections data do not extend to 2100. They are for 2030 and 2050, and are not restricted to the A1B emissions scenario.*
- *We caution that composite temperature projections, based on GCMs grouped into each of the four RFC partitions, may show 'unexpected' temperature results for Australian locations, as the amount of warming (as shown on the Y-axis of Figure 8.1) is for the globe and will vary on local and regional scales. For example, the projected change in the mean temperature in Brisbane over the 21st Century will differ from mean global warming. Projected climates will also differ due to choices of emissions scenario and sensitivity to global warming.*

9 Infilling of trends per degree of global warming

To produce the CF projections data, trends per degree of 21st Century global warming are required for each climate variable of interest for each GCM of interest. These trends per degree of global warming are then applied to historical observations to give future projections. However, in many cases OzClim trends per degree of global warming were not available for specific climate variables. Therefore, trends for those climate variables were estimated by the Queensland Climate Change Centre of Excellence and then 'infilled'.

Of the 19 GCMs selected for use in the CCS project, only five have a complete set of trends per degree of global warming (also called 'patterns of change') from OzClim for all the required climate variables. In addition, since June 1, 2012, trends per degree of global warming have been obtained for two extra highly ranked Hadley Centre GCMs (HADCM3, HADGEM1). The seven GCMs, for which no infilling was required, are listed in Table 9.1.

Table 9.1 GCMs that did not require any infilling, as trends per degree of global warming were available for all the climate variables needed to produce the 'change factors' used in the calculation of the Consistent Climate Scenarios projections data.

GCM name used in Consistent Climate Scenarios Project	**Expert Review Panel recommendation**
HADCM3 HADGEM1 MIROC-H MIROC-M	More likely to produce credible projections
GISS-AOM	Less likely to be reliable
INMCM	Not recommended
CSIRO-MK35	Not assessed, but expected to be better than CSIRO-Mk3.0

Most of the infilling required to produce the CF projections data used quite complex methods. For some GCMs, infilling was almost entirely derived from single model runs, rather than ensembles.

The following information describes the infilling methods used for estimating trends in daily maximum and minimum temperature, vapour pressure, potential evaporation, pan evaporation and solar radiation.

9.1 Estimating trends in daily maximum and minimum temperature

Trends per degree of global warming for maximum and minimum temperature (*Tasmax* and *Tasmin*) were only available from OzClim for seven GCMs (Table 9.2). Trends for these two climate variables have been estimated for all of the other GCMs (Table 9.3).

Table 9.2 GCMs that did not require any infilling for trends per degree of global warming for daily maximum and minimum temperature (*Tasmax* and *Tasmin*).

GCM name used in Consistent Climate Scenarios Project	**Expert Review Panel recommendation**
CSIRO-MK35	Not assessed, but expected to be better than CSIRO-Mk3.0
MIROC-H MIROC-M	More likely to produce credible projections
GIS-AOM	Less likely to be reliable
CSIRO-MK30	Consistently underperformed
BCCR INMCM	Not recommended

Table 9.3 GCMs for which trends per degree of global warming daily maximum and minimum temperature (*Tasmax* and *Tasmin*) have been estimated.

GCM name used in Consistent Climate Scenarios Project	**Trend estimation method**
CCCMA-47 CCCMA-63 CNRM ECHAM5 ECHO-G GDFL-20 GDFL-21 IAP-FGOALS-G10 MRI-GCM232 NCAR-CCSM	Regressed

While two methods were initially available for use in calculating *Tasmax* and *Tasmin* (the *mean ratios* method and the *regression* method), the regression method was the preferred method of use, as it used more information (i.e. precipitable water and cloud cover) from the individual GCM runs.

Regression method

A regression method, developed by Ricketts (2011), has been used to produce a single multiple regression model, which would apply to trends in both maximum and minimum temperature.

As a first step towards estimating these trends, the relationship between the trends in maximum and minimum temperatures, and other climate variables were surveyed using Eureqa™ (Schmidt & Lipson, 2009). Eureqa™ (from Cornell Creative Machines Lab) is a symbolic regression/genetic programming package used to determine a set of candidate predictive relationships. The climate variables and combinations that had the best predictive power were found to be cloud cover (*clt*), precipitable water (*prw*), mean temperature at surface (*tas*), and the two combinations *tas*×*clt* and *tas*×*prw*.

Data were tested on a set of 13 locations around Australia, representing a range of conditions, to derive the 'shape' of the function.

Multiple linear regression was performed for each month using all continental native model grid points, fitted to the following equation. Although OzClim output are available for the INMCM GCM, these were omitted (i.e. not used in the equation) after cross validation diagnostics revealed a severe skewing effect on the regression.

$$T_{p,G*,m} = P_{1,m} \times tas_{p,G,m} + P_{2,m} \times prw_{p,G,m} + P_{3,m} \times clt_{p,G,m} + P_{4,m} \times tas_{p,G,m} \times clt_{p,G,m} + P_{5,m} \times tas_{p,G,m} \times prw_{p,G,m}$$

Equation 1 *General regression model fitted.*

Where *T* is one of *Tasmax* and *Tasmin*, *p* is an individual grid point, *G* is a GCM from the set with known *Tasmax* and *Tasmin*, *p* denotes individual points selected at native GCM resolution, and *G** denotes all GCMs; *m* is a month and *P* is a set of parameters estimated by multiple linear regression. Note that for each month a single set of regression parameters is computed and this regression model is fitted for the same month to all regression models over all grid points. Tables 9.4 and 9.5 present *Tasmax* and *Tasmin* regression constants computed by month and applied to Equation 1.

Finally, the parameters of the function were then applied to all pixels over all available Australian grid points.

Table 9.4 *Tasmax* regression constants (*P*) computed by month and applied to Equation 1. Climate variables are: cloud cover (*clt*), precipitable water (*prw*) and mean temperature at surface (*tas*).

Month	*tas* *(P1)*	*prw* *(P2)*	*clt* *(P3)*	*tas*clt* *(P4)*	*tas*prw* *(P5)*
Jan	1.0750	-0.0001	-0.0845	0.0379	-0.0238
Feb	1.0444	-0.0128	-0.0514	0.0155	-0.0017
Mar	1.0844	-0.0096	-0.0686	0.0258	-0.0221
Apr	1.0171	-0.0245	-0.0465	0.0032	0.0004
May	0.9986	-0.0311	-0.0460	0.0091	0.0208
Jun	0.9903	-0.0545	-0.0378	-0.0205	0.0395
Jul	1.0049	-0.1167	-0.0302	-0.0293	0.0818
Aug	1.0535	-0.0225	-0.0096	-0.0327	-0.0188
Sep	1.0077	0.0218	-0.0462	-0.0036	-0.0199
Oct	1.0778	-0.0037	-0.0485	0.0157	-0.0305
Nov	1.0786	-0.0044	-0.0818	0.0323	-0.0242
Dec	1.0925	-0.0110	-0.0641	0.0213	-0.0200

Table 9.5 *Tasmin* regression constants (*P*) computed by month and applied to Equation 1. Climate variables are: cloud cover (*clt*), precipitable water (*prw*) and mean temperature at surface (*tas*).

Month	*tas* *(P1)*	*prw* *(P2)*	*clt* *(P3)*	*tas*clt* *(P4)*	*tas*prw* *(P5)*
Jan	0.9325	0.0018	0.0455	-0.0075	0.0261
Feb	0.9481	0.0171	0.0367	-0.0028	0.0064
Mar	0.9205	0.0267	0.0475	-0.0056	0.0126
Apr	0.9751	0.0402	0.0168	0.0229	-0.0062
May	1.0215	0.0290	0.0258	0.0157	-0.0205
Jun	0.9719	0.1185	0.0321	0.0142	-0.0673
Jul	0.9662	0.1829	0.0097	0.0399	-0.1136
Aug	0.9115	0.0800	-0.0056	0.0409	0.0046
Sep	0.9573	-0.0101	0.0216	0.0203	0.0534
Oct	0.8802	0.0199	0.0101	0.0077	0.0530
Nov	0.9045	0.0218	0.0464	-0.0058	0.0272
Dec	0.8893	0.0114	0.0384	-0.0029	0.0340

Figure 9.1 presents a comparison of minimum temperature (*Tasmin*) trends to regression derived estimates of the trends for all months for each of the six GCMs.

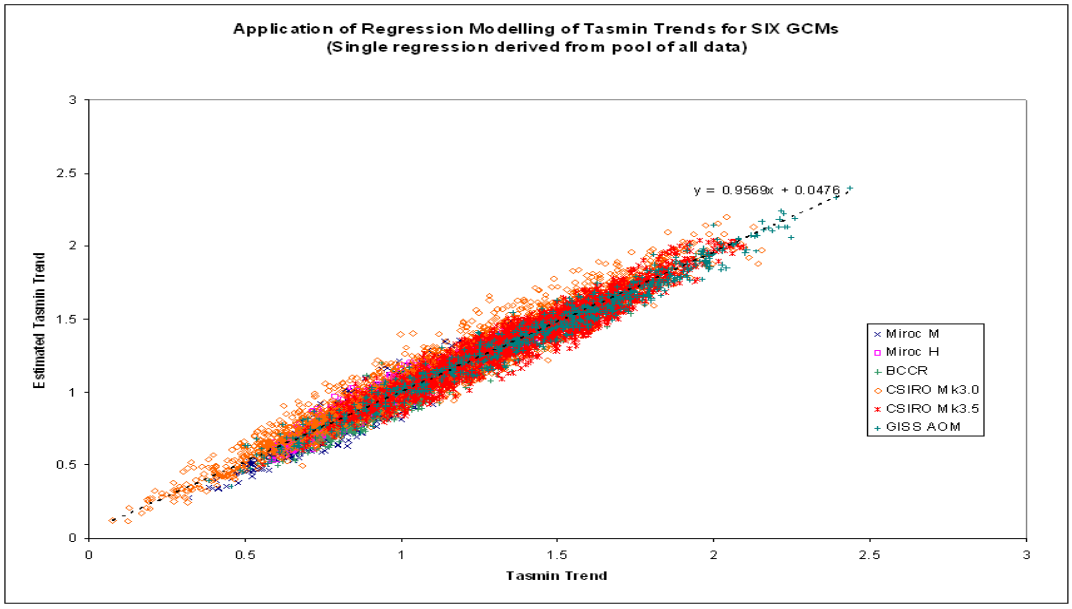


Figure 9.2 Comparison of minimum temperature (*Tasmin*) trends (x-axis) to regression derived estimates of the trends (y-axis) for all months for each of the six GCMs.

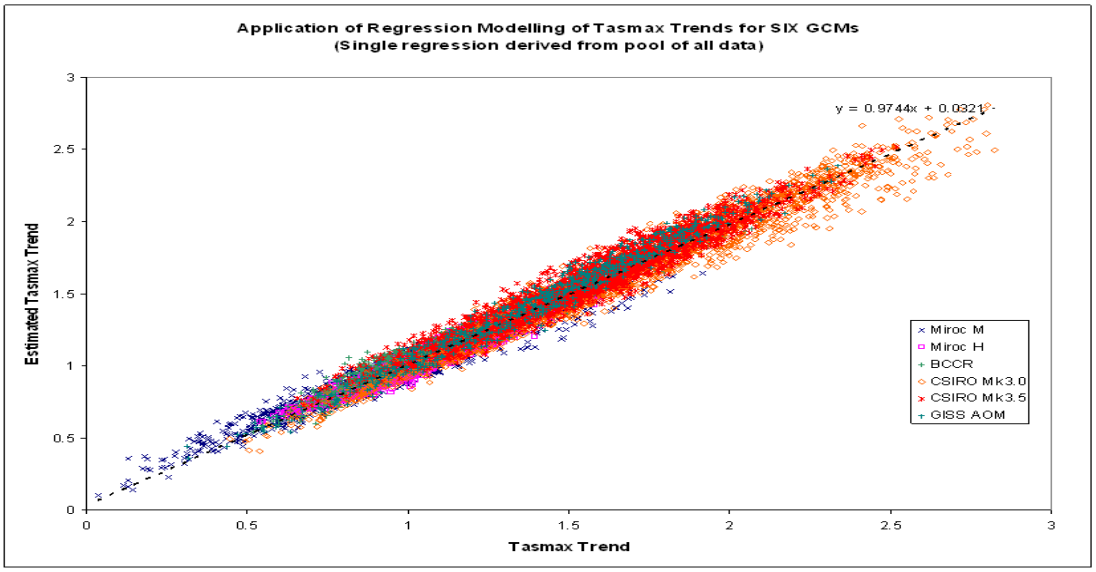


Figure 9.3 Comparison of maximum temperature (*Tasmax*) trends (x-axis) to regression derived estimates of the trends (y-axis) for all months for each of the six GCMs.

A comparison with the ratios method was performed to demonstrate improvements over the ratios methods (Figure 9.2 and Figure 9.3). This comparison shows that: (a) there was a significant reduction in scatter for the regression method compared to the ratios method; and (b) the ratios method had a lower regression coefficient for maximum temperature. The resulting gridded data were checked to ensure the computed *tmax* and *tmin* (*Tasmax, Tasmin*) values correctly bracketed the original *tmean* (*tas*) values, and range checked.

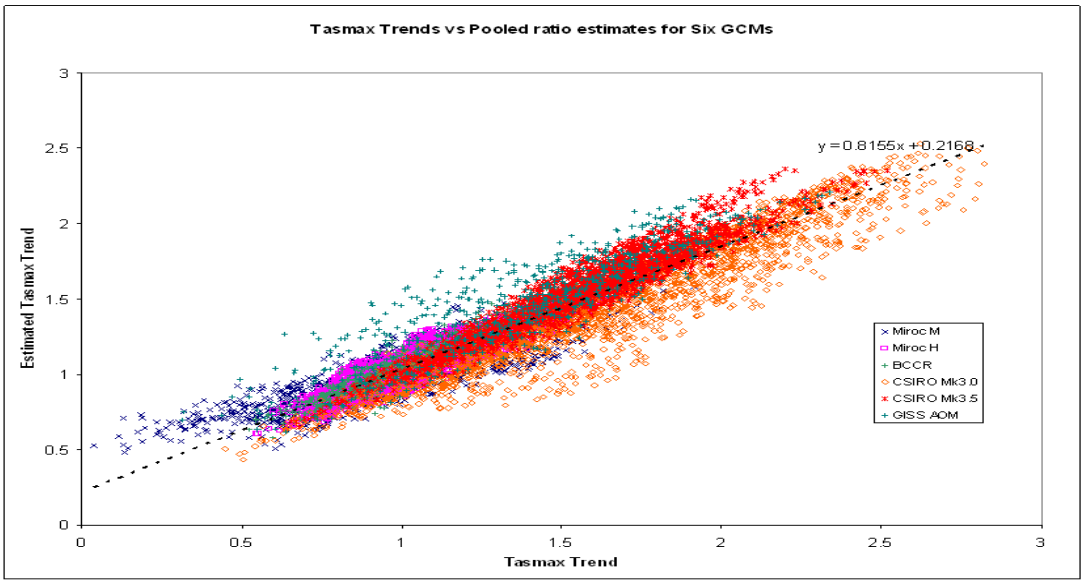


Figure 9.3 Comparison of maximum temperature (*Tasmax*) trends (x-axis) to ratios-method derived estimates of the trends for all months (y-axis) for each of the six GCMs (r^2 = 0.8987). Note: the slope is lower than in Figure 9.2 and there is increased scatter.

Further information, describing the infilling of trends per degree of global warming for missing climate variables, has been documented in:

- Ricketts, J.H. (2011). Estimating trends in monthly maximum and minimum temperatures in GCMs for which these data are not archived. MODSIM Congress, Perth, Australia 12-16 December 2011.

9.2 Estimating vapour pressure

Trends in vapour pressure per degree of global warming, are not directly available from OzClim. Although trends in relative humidity are available from OzClim, it is difficult to estimate changes in vapour pressure, due to corresponding changes in relative humidity, without knowing the simultaneous (9am) temperature. Instead, CSIRO has calculated trends per degree of global warming for surface specific humidity for this project. Therefore, **changes in specific humidity have been used to compute trends in vapour pressure per degree of global warming**.

Method used in CF Version 1 projections

In CF Version 1 projections, trends in vapour pressure had been estimated using standard WMO functions (World Meteorological Organization, Geneva 2008) relating vapour pressure to specific humidity and atmospheric pressure:

$$VP = \frac{SH \times P}{0.62198 \times (1 - SH) + SH}$$

where

VP = vapour pressure in hPa
SH = specific humidity in g(water)/g(moist air)
P = surface atmospheric pressure in hPa.

The constant 0.62198 is the WMO value for the ratio of the molecular weight of water to the average molecular weight of dry air.

As Figure 9.4 shows, over the range of specific humidities and pressures typically encountered in Australia, this function is very nearly linear. A linear approximation is used to compute changes in vapour pressure as a function of changes in specific humidity:

$$\Delta VP = \Delta P + \frac{0.62198 \times VP \times \Delta SH}{SH \times P}$$

where

VP, SH and *P* are as above

ΔVP, ΔSH and ΔP are all relative (percentage) changes.

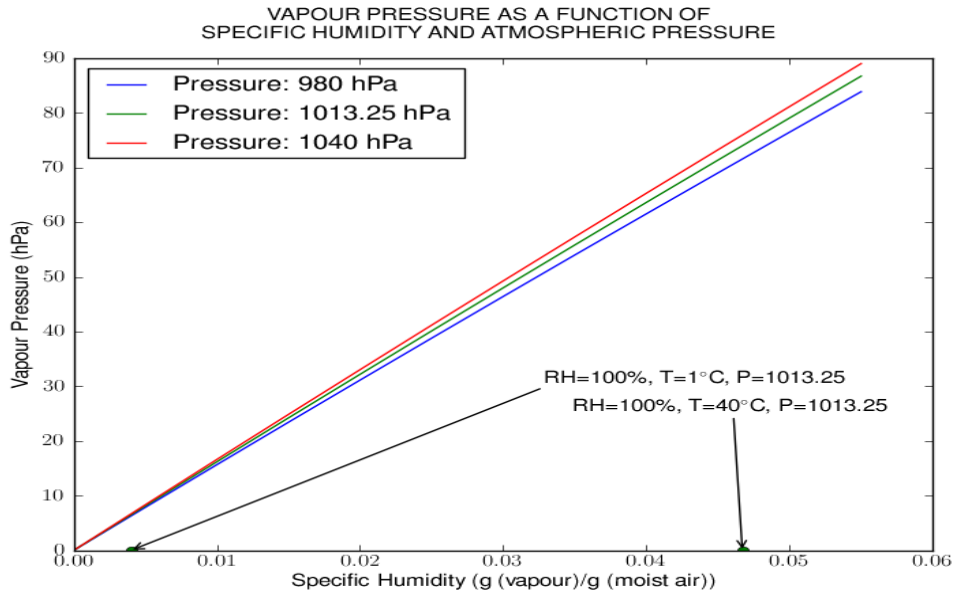


Figure 9.4 Vapour pressure (y-axis) as a function of specific humidity (x-axis) and atmospheric surface pressure, over ranges of values typically encountered in Australia.

While trends in specific humidity were provided by CSIRO, we have assumed zero change in average monthly atmospheric surface pressure for this calculation. We have assumed a fixed baseline atmospheric pressure of P = 1013.25 hPa, with no alteration due to climate change ($\Delta P = 0$). Mean monthly surface pressure changes in the GCM models tend to be small in comparison with changes in specific humidity (about $\pm$0.3% c.f. $\pm$5%) and will have a relatively small impact on the change in vapour pressure. See Figure 9.5

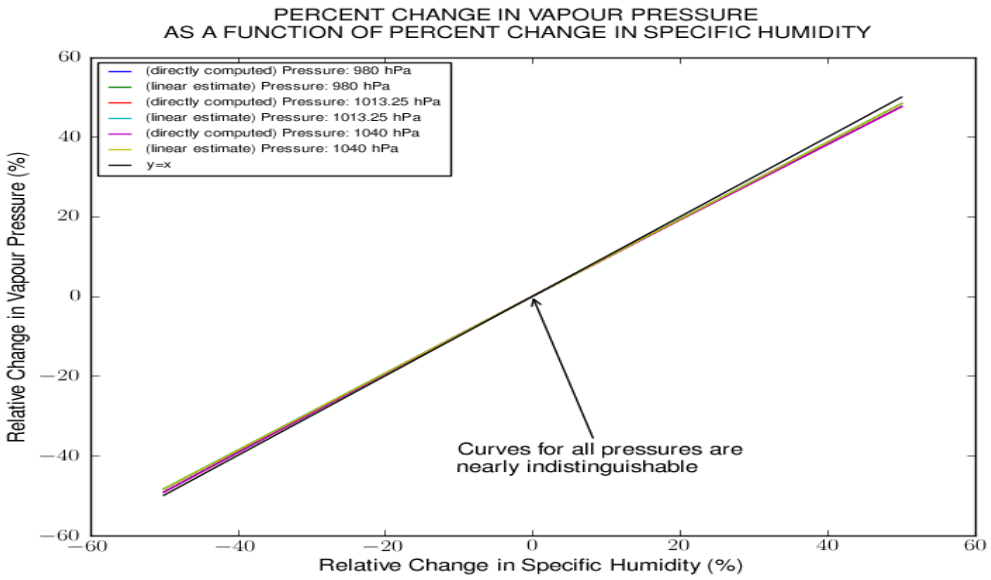


Figure 9.5 Percentage changes in vapour pressure (y-axis) as a function of changes in specific humidity (x-axis), showing the small impact of changes in atmospheric surface pressure.

Method used in CF Version 1.1 and CF Version 1.2 projections

In the Consistent Climate Scenarios project, the climate variable screen specific humidity (*huss*) is an important input into calculation of vapour pressure deficit. This climate variable was not available for a number of GCMs of importance (in fact only four of the ten most preferred GCMs), and hence it becomes necessary to estimate trends.

Butler 1998 gives the following relationship between precipitable water and water vapour partial pressure, $h = \frac{m_w P_0 H}{\rho_l k T_0}$, where

h is precipitable water

m_w, H, ρ_l, k are constants

P_0 is water vapour partial pressure at the surface

T_0 is temperature at the surface.

From this we can derive the following for the derivative of P_0 which should be similar to the trends in *huss*, $\frac{dP_0}{dt} = \frac{1}{B}\left[h\frac{dT_0}{dt} + T_0\frac{dh}{dt} \right]$, where *B* subsumes the constants.

So trends in *huss* ought to be related to trends in precipitable water and surface temperature. However, this is a static model, and climate models involve mobile parcels of air. Furthermore, we are dealing with monthly averaged data.

Technique

As in the estimation of temperature trends, climate model monthly trends were extracted for 13 selected sites distributed within Australia for all climate variables, their present day averages (ave), trend in change per degree global warming and percentage trend per degree of warming (tpc) if available.

The CSIRO supplied climate variables deemed likely to be predictands of *huss* were precipitable water (*prw*), cloud cover (*clt*), temperature (*tas*), precipitation (*pr*) and solar radiation (*rsds*). Additionally, DSITI holds the monthly values for atmospheric specific humidity at standard pressures (*hus*) and a separate investigation was carried out to determine the feasibility of predicting *huss* directly from trends in *huss* at some low pressure level. In the later event the relationship seems to break down near the coast, and so a measure of distance from coast was added to compensate for this.

After experimentation, the GCMs listed in Table 9.6 were selected for the availability of *huss* plus the nominated predictands.

Table 9.6 GCMs selected for the availability of specific humidity (*huss).*

GCM name used in Consistent Climate Scenarios Project	**Expert Review Panel recommendation**
CSIRO-MK35	Not assessed, but expected to be better than CSIRO-Mk3.0
MIROC-H MIROC-M	More likely to produce credible projections
CCCMA-47 (added later) CCCMA-63 GIS-AOM IAP-FGOALS-G10 MRI-GCM232 (omitted later)	Less likely to be reliable
CNRM	Consistently underperformed
BCCR INMCM	Not recommended

Euriqua™ was used to select candidate variables and simple combinations of variables for each month from 13 candidate sites within Australia. The final runs of Euriqua™ attempted to fit the following relation.

huss_tpc = f(hus_92500_trend, hus_92500_ave, pr_tpc, prw_tpc, prw_ave, tas_trend, clt_trend, tas_prw, tas_pr, pr_prw, rsds_tpc, dist)

where

huss = screen specific humidity
hus_92500 = air column specific humidity at 925 HP
pr = precipitation
prw = precipitable water
tas = mean temperature at surface
clt = cloud cover
rsds = solar radiation
"*_tpc*" = percentage trend per degree of global warming
"*_ave*" = model average of present (1975-2004)
"*_trend*" = trend per degree of global warming
dist = distance from coast.

For each month, Euriqua™ ran the above model for 10 minutes and then the partial functions from the resulting "fitted" equations and the equation with the highest r^2 were recorded. Note that differing months yielded somewhat differing results, and hence the following regression model was tested using multiple linear regression.

$$Huss_{p,G^*,m} = P_{1,m} \times prw\_tpc_{p,G,m} + P_{2,m} \times tas\_trend_{p,G,m} + P_{3,m} \times dist_p + P_{4,m} \times pr\_tpc_{p,G,m} \times dist_p + P_{5,m} \times prw\_tpc_{p,G,m} \times tas\_trend_{p,G,m} + P_{6,m} \times hus\_ave^{92500}_{p,G,m} \times tas\_trend_{p,G,m} \times dist_p + P_{7,m} \times clt\_ave_{p,G,m} \times tas\_trend_{p,G,m} + P_{8,m} \times prw\_tpc_{p,G,m} \times clt\_trend_{p,G,m} + P_{9,m} \times tas\_trend_{p,G,m} \times hus\_trend^{92500}_{p,G,m} + P_{10,m} \times hus\_trend^{92500}_{p,G,m} + P_{11,m} \times prw\_tpc_{p,G,m} \times pr\_tpc_{p,G,m} + P_{12,m} \times rsds\_tpc_{p,G,m}$$

The *CCCMA-47 (CGCM3.1(T47))* model was added to the above GCMs, using estimated RSDS tpcs (since *rsds* was not supplied for this model). *Huss* trends associated with the *MRI-GCM232* GCM were totally non-correlated with any of the predictands (contrary to all other models), so this model was omitted.

As in Section 9.1, multiple linear regression was then performed using the chosen model. The regression statistics (Table 9.7) indicated that parameters 3, 4, 6 and 11 were not different from zero, so the final regression used was:

$$Huss_{p,G^*,m} = P_{1,m} \times prw\_tpc_{p,G,m} + P_{2,m} \times tas\_trend_{p,G,m} + P_{5,m} \times prw\_tpc_{p,G,m} \times tas\_trend_{p,G,m} + P_{7,m} \times clt\_ave_{p,G,m} \times tas\_trend_{p,G,m} + P_{8,m} \times prw\_tpc_{p,G,m} \times clt\_trend_{p,G,m} + P_{9,m} \times tas\_trend_{p,G,m} \times hus\_trend^{92500}_{p,G,m} + P_{10,m} \times hus\_trend^{92500}_{p,G,m} + P_{12,m} \times rsds\_tpc_{p,G,m}$$

Table 9.7 Final values for the multiple linear regression coefficients (*P*) for each month. Climate variables are: precipitable water (*prw*), mean temperature at surface (*tas*), cloud cover (*clt*), air column specific humidity at 925 HP (*hus_92500*) and solar radiation (*rsds*).

Month	*prw_tpc*	*Tas_trend*	*prw_tpc tas_trend*	*clt_ave*	*prw_tpc * clt_trend*	*hus_92500_trend * tas_trend*	*hus_92500_trend*	*rsds_tpc*
Jan	0.8158	-0.3472	-0.0474	0.0642	-0.0302	558.9261	-607.9183	0.1705
Feb	0.7709	-0.2694	0.0048	0.3657	-0.0418	588.6248	-564.2603	0.2041
Mar	0.9153	-1.1877	-0.0368	-0.1795	-0.0086	994.6107	-971.3263	0.0919
Apr	0.9238	0.2712	-0.1711	0.2522	-0.0566	671.7763	-636.5437	-0.1546
May	1.0603	0.1438	-0.2990	-0.3151	0.0036	762.1897	-575.5986	-0.1726
Jun	1.0133	0.5494	-0.3136	-0.5790	-0.0198	1597.5352	-1268.8066	-0.8551
Jul	1.0176	0.0242	-0.1713	-0.7287	0.0034	-2122.3183	2320.9253	-0.7793
Aug	0.9297	1.3073	-0.3551	-0.6341	-0.0028	1612.0010	-1155.6561	-0.7550
Sep	0.9173	-0.1568	-0.1663	-0.2789	-0.0643	384.0680	-315.6471	-0.4853
Oct	0.9639	-2.0256	-0.0366	-1.1688	0.0234	774.2827	-888.5436	-0.6362
Nov	0.9230	-1.8634	0.0214	-0.1456	-0.0265	-344.7397	422.3786	0.2942
Dec	0.9806	-2.2829	0.0658	-0.4819	0.0318	411.5138	-446.5273	0.3866

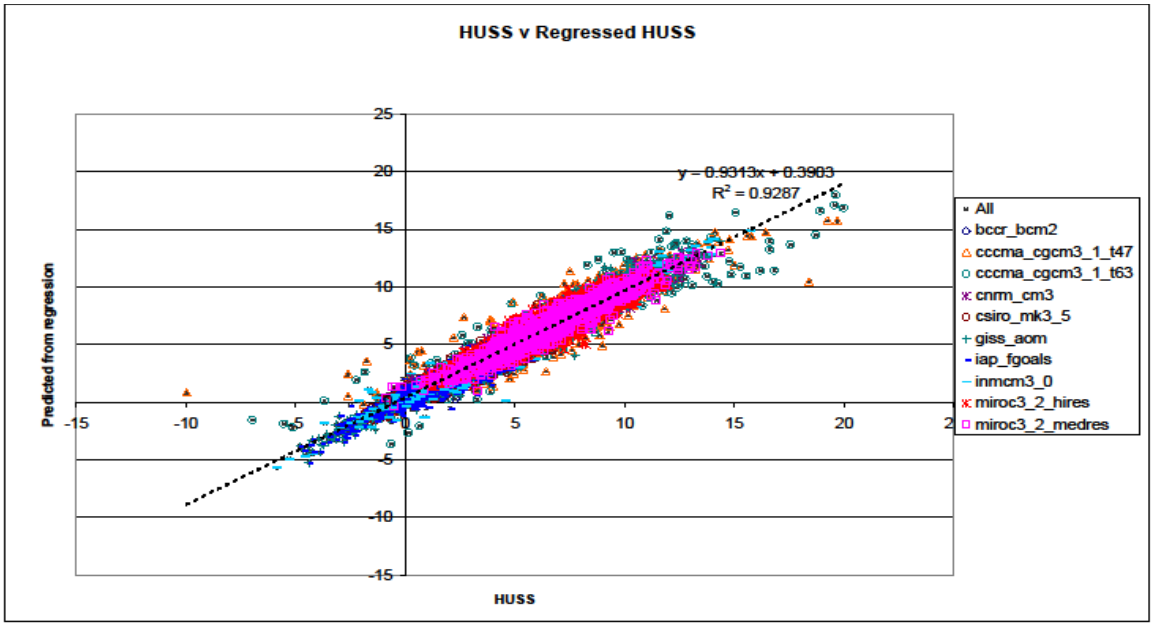


Figure 9.6 Regression models (y-axis) vs *huss* (screen height specific humidity, x-axis) showing each GCM plotted against the prediction if each model is regressed against only its own predictands. For example, MIROC3.2 (medres) *huss* predicted from coefficients derived for that GCM only. This measures the internal consistency of the regression, and shows that for the models included in the calculation *huss* is highly predictable.

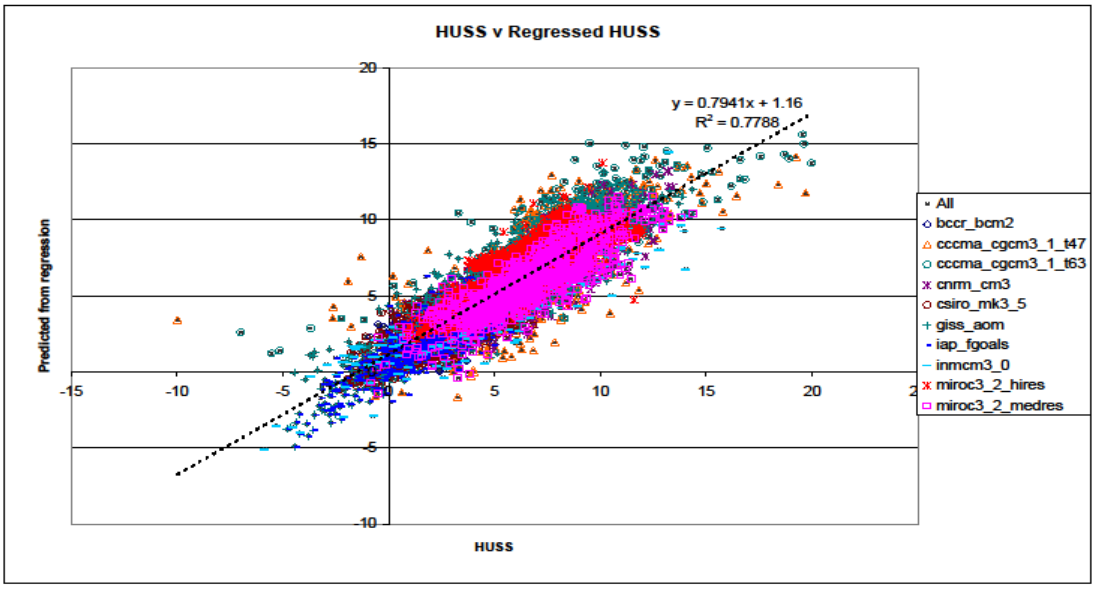


Figure 9.7 The same as Figure 8.6, but showing the GCM *huss* (x-axis) plotted against the predicted values (y-axis) using the coefficients in Table 9.7.

9.3 Estimating potential evaporation and pan evaporation

As pan evaporation is not a variable directly available from GCMs, pan evaporation data were initially calculated using OzClim Areal Wet Area “potential evaporation” trends, based on Morton’s method (Morton, 1983). This initial approach was taken, since trends in Areal Wet Area potential evaporation should be highly correlated with trends in pan evaporation. A refinement was made in CF Version 1.1, with OzClim trends for solar radiation and vapour pressure being adopted to calculate trends in pan evaporation. CF Version 1.1, daily pan evaporation has been re-computed using the same synthetic pan evaporation calculation method that is used in SILO (Rayner, 2005).

9.4 Estimating solar radiation

In this project, the climate variable downward short wave radiation (*rsds*) is an important input into calculation of vapour pressure deficit. As *rsds* was not readily available on PCMDI for two GCMs of interest (CCCMA-47 and ECHO-G), it became necessary to estimate trends for those GCMs.

The first step in estimating solar radiation took an approach to find candidate relationships between the available climate variables and *rsds,* using a correlation relationship to give reasonable estimates of trends in *rsds.* This included using the reciprocal top of atmosphere radiation (*Ra*) being added to the standard climate variables. After experimentation, several GCMs (Table 9.8) were selected for the availability of *rsds* plus the nominated predictands.

Table 9.8 GCMs selected for the availability of downward short wave radiation (*rsds).*

GCM name used in Consistent Climate Scenarios Project	**Expert Review Panel recommendation**
CSIRO-MK35	Not assessed, but expected to be better than CSIRO-Mk3.0
MIROC-H MIROC-M	More likely to produce credible projections
CCCMA-63 GISS-AOM IAP-FGOALS-G10 MRI-GCM 232	Less likely to be reliable
CNRM	Consistently underperformed
BCCR INMCM	Not recommended

Trends in solar radiation as a percentage of the average are computed from the following equation:

rsds_tpc = clt_ave(P1 + P2*clt_trend + P3*pr_tpc)*

*+(P4*clt_trend + P5*pr_tpc + P6*prw_tpc)/Ra*

where

clt = total cloud fraction
pr = precipitation
prw = precipitable water
Ra = reciprocal top of atmosphere radiation
"*_tpc*" = percentage trend per degree of global warming
"*_ave*" = model average of present (1975-2004)
"*_trend*" = trend per degree of global warming.

Multiple regression

The next step taken to estimate solar radiation was drawn from the GCMs at model native resolution. All data points over Australia for each of the climate variables from each Global Climate Model were extracted. The data was separated into months and the above regression equation was fitted to all of the data points for that month, pooling all the available points from all of the GCMs. The result was a set of regression coefficients for each month (Table 9.9). Additionally, the multiple linear regression was performed on a per GCM basis to allow us to test the strength of the regression model predictions (Figure 9.8).

Table 9.9 Regression parameters found for each of the parts of the regression model.

Month	*Clt_ave*	*Clt_ave*clt*	*clt_ave*pr*	*clt/Ra*	*Pr/Ra*	*Prw/Ra*	Residue
Jan	0.0003	-0.0032	-0.0007	-14.4229	0.1190	-0.9620	543.1265
Feb	0.0004	-0.0017	-0.0019	-12.0832	0.7943	-1.2286	948.7009
Mar	0.0097	-0.0006	-0.0008	-10.7869	-0.2588	-2.1887	555.5375
Apr	0.0033	0.0000	-0.0001	-17.0826	-0.5170	-1.5816	549.2540
May	0.0052	-0.0196	-0.0005	5.6363	-0.3182	-1.2720	871.0217
Jun	0.0094	-0.0325	0.0001	4.8687	0.0072	-2.0298	1996.3467
Jul	-0.0205	-0.0212	-0.0006	-6.9712	-0.0339	0.7876	2369.9871
Aug	0.0059	-0.0042	-0.0013	-11.4853	0.1778	-0.4918	1280.0288
Sep	0.0040	0.0043	-0.0004	-26.0600	-0.0607	-1.6455	624.5360
Oct	0.0032	-0.0091	-0.0004	-10.1548	0.0931	-1.3102	451.3216
Nov	0.0039	-0.0017	-0.0002	-15.3375	0.1875	-2.5574	326.1852
Dec	0.0179	-0.0001	0.0000	-16.8268	-0.2668	-3.9200	543.2014

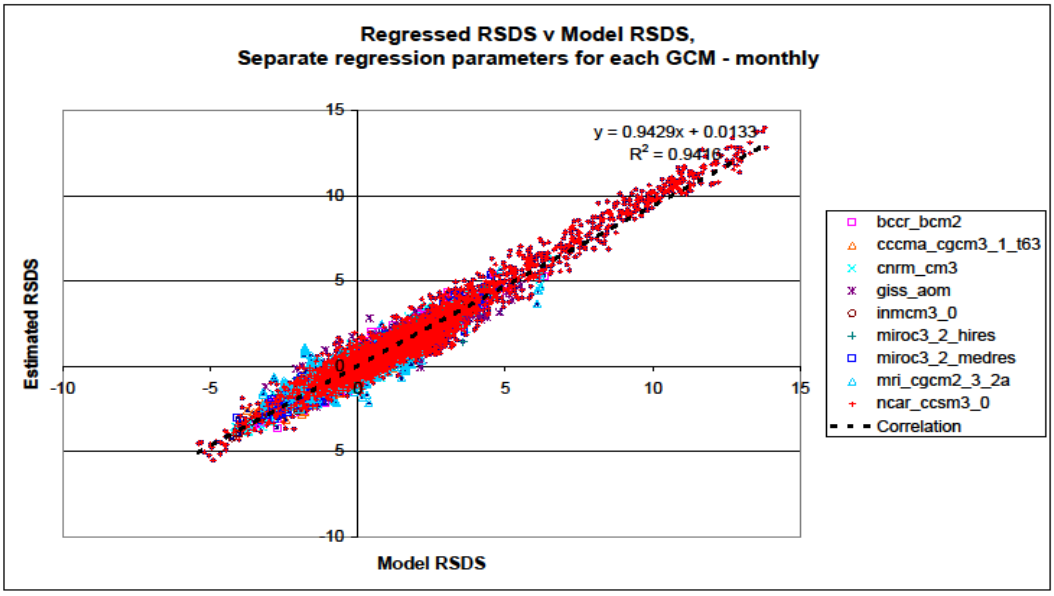


Figure 9.8 Plot of *rsds* (% trend, x-axis) for individual GCMs against the prediction for that GCM (y-axis) if the regression parameters are derived for each individual GCM (and month). This allows us to say, in this case, that all GCMs show the same general relationship between climate variables, and the regression model produces a linear trend.

It should be noted that trends in downward short wave solar radiation appear to relate to trends in cloudiness and related water variables. Note also, that despite the signs being *shown* as positive above, when the signs of the coefficients are taken into account, the trends in *rsds* are generally inverse to trends in cloudiness as expected. It is also consistent to find that the trends are inversely proportional to the top of atmosphere radiation. Lastly, an analysis of multiple regression residues showed that the winter months are not as well estimated as other months.

9.5 Summary of infilling

In summary, of the 19 GCMs currently available in the Consistent Climate Scenarios project, no infilling of trends per degree of 21st Century global warming was required in order to compute 'change factors' for the associated rainfall projections data.

However, several GCMs did not have trends per degree of 21st Century global warming for specific climate elements, which include solar radiation, humidity and maximum and minimum air temperature, so the DSITI has adopted multiple regression techniques to formulate these missing trends. Of those GCMs that had missing trends per degree of 21st Century global warming, 10 GCMs required infilling for maximum and minimum temperature and five GCMs required infilling for humidity. Less infilling was required for other climate variables. Further information related to the infilling for individual GCMs is presented in Table 9.10.

Table 9.10 State of infilling for missing trends per degree of global warming for specific climate variables at 30 May 2012.

GLOBAL CLIMATE MODELS AND INFILLING as at 30 May 2012

				Infilled			Difficult to infill, more data (i.e. water vapour) required		Model recommended by Suppiah	Model not in Suppiah's set		Low priority - poor model
Expert Review Panel's ranking of GCM	GCM name used in OzClim and Consistent Climate Scenarios	Expert Review Panel's reccomendation	Infilling completed	Total cloud fraction (clt)[1,3,6]	Surface specific humidity (huss)[2]	Precipitation (pr)[6]	Precipitable water (prw)[1,3,6]	Surface downwelling short-wave radiation (rsds)[3,6]	Mean surface air temperature (tas)[1,3]	Daily max & min surface air temperature (tasmax, tasmin)		Wet area potential evaporation (wap)[4]
1	HADCM3	More likely to produce credible projections	May 2012	✓	✓	✓		✓	✓	✓	✓	✓
2	MIROC-H		Sep 2010	✓	✓	✓	✓	✓	✓	✓	✓	✓
3	GFDL-21		Apr 2011	✓	Regressed	✓	✓	✓	✓	Regressed		
4	GFDL-20		Apr 2011	✓	Regressed	✓	✓	✓	✓	Regressed		
5	MIROC-M		Sep 2010	✓	✓	✓	✓	✓	✓	✓	✓	✓
6	ECHO-G		Apr 2011	✓	Regressed	✓	✓	Regressed	✓	Regressed		
7	HADGEM1		May 2012	✓	✓	✓		✓	✓	✓	✓	✓
8	ECHAM5		Apr 2011	✓	Regressed	✓	✓	✓	✓	Regressed		
9	MRI-GCM232	Less likely to be reliable	Sep 2010	✓	✓	✓	✓	✓	✓	Regressed		✓
10	NCAR-CCSM		Apr 2011	✓	✓	✓	✓	✓	✓	Regressed		✓
11	CCCMA-63		Sep 2010	✓	✓	✓	✓	✓	✓	Regressed		✓
12	GISS-AOM		Sep 2010	✓	✓	✓	✓	✓	✓	✓	✓	✓
13*	INMCM	Not recommended	Sep 2010	✓	✓	✓	✓	✓	✓	✓	✓	✓
14	CCCMA-47	Less likely to be reliable	Apr 2011	✓	✓	✓	✓	Regressed	✓	Regressed		
15	IAP-FGOALS-G10		Sep 2010	✓	✓	✓	✓	✓	✓	Regressed		✓
16	CSIRO-Mk30	Consistently under performed	Apr 2011	✓	Regressed	✓	✓	✓	✓	✓	✓	
17	CNRM		Apr 2011	✓	✓	✓	✓	✓	✓	Regressed		
18	ISPL-CM4 (not used in project)											
19	BCCR	Not recommended	Apr 2011	✓	✓	✓	✓	✓	✓	✓	✓	
20	GISS-ER (not used in project)											
21	NCAR-PCM1 (not used in project)											
22	GISS-EH (not used in project)											
NOT ASSESSED	CSIRO-MK35	Not assessed	Sep 2010	✓	✓	✓	✓	✓	✓	✓	✓	✓

NOTES

✓ Trend per degree global warming available from OzClim

Version 1 projections data (Sep 2010), Version 1.1 (Apr 2011), Version 1.2 (May 2012).

[1] Trends in total cloud fraction, preciptiable water and mean surface air temperature used to calculate trends in **daily maximum and minimum air temperature**.
[2] Version 1: Trends in surface specific humidty used to calculate trends in **vapour pressure**.
[3] Version 1.1 & 1.2: Trends in total cloud fraction, preciptiable water, downwelling short-wave radiation and mean surface air temperature used to calculate trends in **vapour pressure**.
[4] Version 1: Trends in Morton's wet area potential evaporation used to calculate trends in **pan evaporation**.
[5] Version 1.1 & 1.2: Trends in downwelling short-wave radiation and vapour pressure used to calculate trends in **pan evaporation**.
[6] Version 1.1 & 1.2: Trends in total cloud fraction, reciprocal top of atmosphere radiation, precipitation and precipitable water used to calculate trends in **solar radiation**.

Trends in surface relative humidity, wind speed and ocean variables (sea surface air temperature and ocean salinity) are avaialable in OzClim, but have not been used in the Consistent Climate Scenarios project, to date.

* The INMCM GCM, previously rated 'likely to be less reliable', is no longer recommended for use due to unstable drift in the model. The rank for this model will be adjusted.

10 Known limitations of CF projections data

This section of the User Guide provides users with information about known limitations of the CF data projections data, accompanied by some caveats and guidelines. It remains the user's responsibility to fully evaluate inputs to, and outputs from, biophysical models.

10.1 Base-period selection

The CF projections data have not been de-trended in any way and users of the data need to be aware that their choice of historical base-period data can make a difference in the statistics of the climate variables. This is because climate fluctuates over time, particularly due to the influence of annual and decadal climate drivers (i.e. El Niño- Southern Oscillation (ENSO) and the Interdecadal Pacific Oscillation (IPO)) and also due to longer term natural and anthropogenic climate influences. The compilation of statistics using a relatively long base-period is more likely to capture these trends.

The examples presented in Figure 10.1 and Table 10.1 show how the University of Queensland (Gatton) historical climate data and CF projections data can differ according to the selected historical base-period.

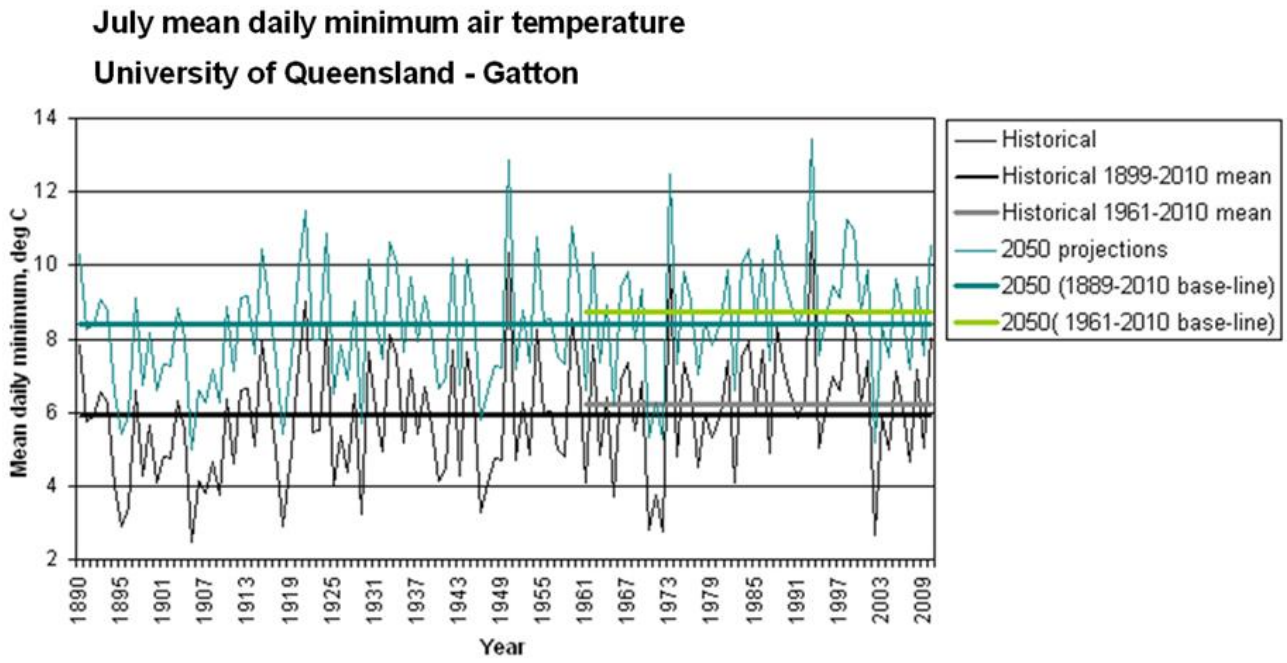


Figure 10.1 Graph showing how the University of Queensland - Gatton (Location Code 040082) CF Version 1.1 projections data differ for 2050, depending on the historical base-period that is selected. The SILO historical data (black) are overlaid with Consistent Climate Scenarios CF Version 1.1 projections data (green) for July 2050. The projections data use MIROC-H, A1FI and high climate warming sensitivity. Data will differ for other sites and projections scenarios.

Table 10.1 Analysis of SILO historical and projected 2050 July climate data for the University of Queensland - Gatton (Location Code 040082), showing changes in climate statistics for several climate variables due to the use of different historical base-periods. Statistics will differ for other sites and projections scenarios.

July	Base-period	Mean monthly Rainfall	Mean daily maximum temperature	Mean daily minimum temperature	Mean days with frost per month (screen minimum less than 2.0ºC)
SILO historical data	1889-2010 (122-yrs)	45.6 mm	20.5ºC	5.9ºC	3.8
	1961-2010 (50-yrs)	45.9 mm	20.8ºC	6.2ºC	1.5
	1980-2010 (30-yrs)	36.0 mm	21.1ºC	6.6ºC	0.7
2050 projections (MIROC-H GCM, A1F1 emissions scenario and high climate warming sensitivity)	1889-2010 (122-yrs)	39.1 mm	22.6ºC	8.4ºC	0.5
	1961-2010 (50-yrs)	39.3 mm	22.9ºC	8.7ºC	0.3
	1980-2010 (30-yrs)	30.9 mm	23.2ºC	9.1ºC	0.1

Notes

- *In the CF Version 1.1 data climate 'change factors' were applied to a measured (historical) sequence from 1889-2010. However, in the web-based CF Version 1.2 the historical baseline is restricted to data from 1960 onwards.*
- ***For applications model evaluation, we recommend usage of a 1960-2010 base period, as the quality of post-1960 historical climate data is higher.***
- *The use of long (i.e. multi-decadal), rather than short, time sequences will allow users to better investigate impacts of year-to-year and decade-to-decade variability in rainfall and other climate elements.*
- ***The period from 1960 to 2010 encompasses natural climate variability (i.e. droughts and floods) due to fluctuations in ENSO as well as opposite phases of the IPO.*** *For example:*
  - *IPO phase changes from 'Cool' to 'Warm' in 1978 and from 'Warm' to 'Cool' in 1999;*
  - *strong El Niño's[8] in 1965, 1972/73, 1982/83, 1991/92, 1997/98 and 2009/10; and*
  - *strong La Niña's in 1973/74, 1975/76 and 1988/89, based on the NOAA Oceanic Niño Index (NOAA, 2011).*
- *The mean and shape of the probability distribution will vary according to the base-period used.*
- *We recommend the use of patched-point data sets, rather than interpolated (gridded) data, where available. Interpolated data, although useful, may have low accuracy in isolated station-poor regions, especially in the pre 1957 period, due to the low density Australian climate station network until then.*
- ***The post 1957 interpolated data is more accurate than pre 1957 interpolated data*** *(QCCCE, 2009 in preparation). Un-detected 'bad data' can have a large effect on the interpolated data, especially in data sparse areas (QCCCE, 2008 in preparation).*
- *The use of the post 1957 data is consistent with the base-period that is used in the QM approach.*
- *Users may wish to further subsample or randomise the 2030/2050 time sequences to suit their project requirements, although this may change the statistics of runs of above and below average rainfall.*

[8] based on the NOAA Oceanic Niño Index (NOAA, 2011).

10.2 Capture of anomalous data in Log warning files

Log warning files have been provided, with the CF data, for each point-location and GCM model run. The Log warning files hold information to alert users to any problematic data and have been described earlier (see Section 3.4 of the User Guide). For example, a log will be generated in a Log warning file whenever pattern scaling produces negative projections or where data lie outside the bounds of what may reasonably be expected:

- In the cases where trends in climate variables have been logged as 'Implausible', the associated projections data have been re-set to more realistic values (according to Table 3.1). For example, this means that negative rainfall totals will not occur (such values could case biological models to fail).
- In some cases, usually individual days, anomalous values may occur. These values may be derived from one of three sources, which are: 1) the raw data; 2) interpolation; or 3) the modification to "climate changed data".
- Users should also note that any precision in the values (i.e. change rates) listed in the Log warning files is for calculation purposes only and that this precision will not occur in reality.

10.3 Emissions and CO_2-stabilisation scenarios

Climate projections data using six SRES emissions scenarios and two CO_2-stabilisation scenarios are available for use in the Consistent Climate Scenarios project. Users should be aware that:

- We strongly recommend using the A1FI emissions scenario, as it most closely represents the current trend in global CO_2 emissions. A1FI also represents the most extreme global warming risk analysed to date.
- A1B is the scenario for which amounts of global warming and associated climate warming sensitivities were available for the greatest number of GCM runs through PCMDI. Whilst runs for A2 and B2 were also submitted to PCMDI, these were not as complete. Where there was any missing data for any climate variable in A1B runs, A2 runs were used for that GCM.
- Pattern-scaling has been used to derive amounts of global warming and associated climate warming sensitivities for all emissions scenarios, normalising them to the responses computed using the MAGICC simple climate model. This includes the A1B and A2 scenarios.
- The low-end, less extreme, 'B' family of SRES emissions scenarios are looking increasingly unlikely. The inclusion of these low-end scenarios, in modelling the range of uncertainties for climate change projections, has the potential to bias outputs and hence under-estimate the effects of climate change.

As the 21st Century concentration pathways for the six emissions scenarios and two CO_2-stabilisation scenarios are uncertain, it is possible that they may under or over shoot the proposed trajectories.

10.4 Downscaling from Global Climate Models

A typical coarse-grained Global Climate Model (GCM) is computed at a resolution of about 2^{o}, giving about 16,200 grid points over the whole globe, of which, some 350 grid points are likely to occur within the Australian bounding rectangle (10S to 45S, 115E to 155E) and less over the Australian continental land area[9].

Therefore, in attempting to produce analyses of future trends over the Australian continent, we are constrained to using less than two percent of the available information from GCMs. As a consequence, this creates increased sample variance and:

- the range of available GCMs produce widely differing estimates of both simulated 20th Century and projected 21st Century trends in rainfall over Australia; and similarly
- GCMs also give a diversity of 20th Century Australian continental mean temperature trends.

We assume the spatial variation in climate variable response is:

- more related to a GCM itself than individual runs, or the forcing scenario; and
- is approximately linear in response to global warming in the model.

Therefore, we can scale the local climate response according to global warming.

In this project, information obtained from GCM grid-points has been interpolated over Australia on a common 25km x 25km base. However:

- the downscaling produced by this interpolation provides utility in terms of application, but it does not imply any increase in accuracy over the native, typically 150-250km^2 GCM resolution.

10.5 The calculation of trends per degree of global warming

Regression has been used to calculate trends per degree of global warming for 2000-2100, against GCM data, which may:

- contain “outliers”; or
- may be inherently non-linear; and/or
- the base-line GCM model data may be implausibly low.

The following may produce impossible percentage trends per degree of global warming values:

- an implausible trend value is divided by a plausible base-line value; or
- a plausible trend value is divided by an implausibly low base-line value.

In either event, when the trend per degree of global warming value is then multiplied by the observed value, the error is propagated.

[9] Australia has a land area equivalent to 1.5% of the Earth’s total area.

In cases where OzClim trends per degree of global warming for some climate variables are not available for particular GCMs, the data for those climate variables have been estimated and then 'in-filled', using either ratios or multiple regression techniques.

Various anomalies were found in some of the trend per degree of global warming files supplied by CSIRO for this project. A search of monthly trend per degree of global warming on a grid-cell by grid-cell basis over all GCM models, using a filter of +/- 50% (for a nominal degree of global warming), revealed some anomalous large magnitude 'change factors' that would become much larger when scaled by one to four degrees of global warming. The anomalies discovered were mainly in rainfall and evaporation trend files.

The most common effects are:

- projections of extreme drying trends;
- unreasonably large increases in wet area evaporation at some locations; and
- significant errors, not only of scale of trend but also potentially of sign of trend, leading to a reduction in confidence in projections.

As an example, one GCM model had an implausibly low base-line 30-year monthly average rainfall of 7.9 x 10^{-6} mm (Fig. 10.2a). The resulting trend per degree of global warming was a -2.6 x 10^{7} percent change from base per degree of global warming (Fig. 10.2b). This corresponds to an original trend of -2.1 mm per degree of global warming which is almost, but not quite plausible - given an observed monthly average of 2 mm (Fig. 10.2c).

Note that wet area evaporation is not used in the final calculation, in which changes in pan evaporation are estimated as a function of changes in vapour pressure deficit and changes in solar radiation.

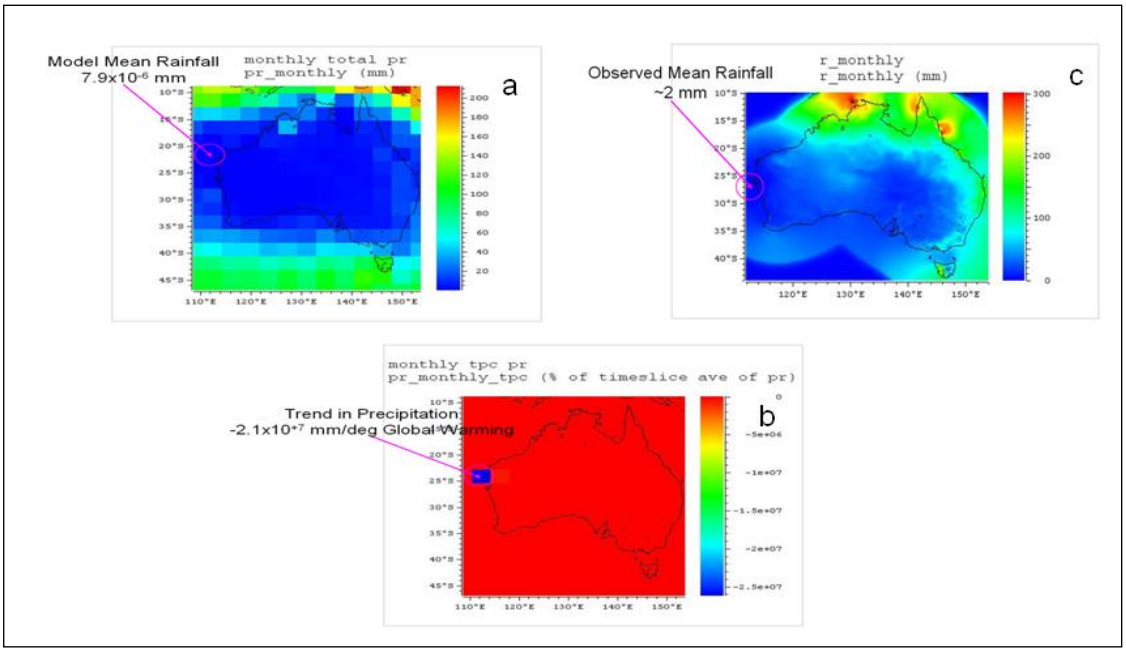


Figure 10.2 Illustrating limitations associated with downscaling from GCMs: (a) An extract of "pre-OzClim" model simulated base-line climate, showing the mean rainfall at one location; (b) a consequential anomalously extreme downward trend in percentage change per degree of global warming and (c) Bureau of Meteorology observational data from the same region, showing a 2 mm average rainfall for the month as compared to 1 nanometre shown by the GCM model observed monthly average.

Table 10.2 presents an example of several obvious anomalies found in the trend files supplied by CSIRO. In all these cases, they are change per degree of global warming expressed as a percentage of model base-line climate, and known as “tpc” files. These are derived directly from OzClim, being the intermediate trend files produced by interpolation from Global Climate Model (GCM *tpc*) files and cached in OzClim. In OzClim the data output using the trend and degree of global warming are clamped to plausible values, so anomalies are often not visible; the issue of anomalies then arises when pattern-of-change data is published.

Table 10. 2 Selected examples, where rainfall in a few GCMs are affected by anomalous trends in OzClim. Columns are GCM model name, Climate variable, Month, and for all trend per degree of global warming (tpc) data for the month, the mean, standard deviation, minimum and maximum change in rainfall per degree of global warming expressed as a percentage of GCM base-line (1975-2004) climate. Errors marked in red exceed 100 percent. These GCMs have been used in the CF (Version 1 and 1.1) Consistent Climate Scenarios projection data.

Error flags for anomalous trends per degree of global warming							
GCM Name	**Climate variable**	**Month**	**Mean trend in rain %**	**Standard deviation %**	**Minimum %**	**Maximum %**	**Error flag**
CCCMA-63	Rainfall	6	6.43	11.99	-7.53	**101.46**	extremes out of range in tpc
CSIRO-MK35	Rainfall	9	-19.49	22.01	-99.33	**131.09**	extremes out of range in tpc
	Rainfall	10	-34.32	57.77	**-545.89**	15.98	extremes out of range in tpc
MRI-GCM232	Rainfall	10	-14.48	30.14	**-338.43**	13.26	extremes out of range in tpc

10.6 Known issues related to the calculation of ‘change factors’

The following matters need to be considered in regard to the pattern-scaling technique and GCM ensemble members, from which trends per degree of global warming (also called patterns of change) and hence ‘change factors’ are calculated:

Pattern-scaling

- Pattern scaling, the basis of the ‘change factor’ approach, is based on two main assumptions:
  1) Using GCMs, all projected changes in the future climate follow a linear relationship between global warming and the variables of interest. This assumption is applied even when the climate variables are known to have a non-linear relationship between them.
  2) The projected pattern of a climate variable in the future, according to any GCM, is essentially independent of the SRES scenario and of time. The error limits of this method are not well understood for many climate variables.
- The Consistent Climate Scenarios (CCS) project utilises the pattern-scaling technique to compute trends per degree of global warming at specific locations in Australia for a number of climate variables. However, the pattern-scaling technique has only been validated for temperature and precipitation.
- Not all of the climate variables of interest to this project were available in all GCMs:
  – Of the 19 GCMs used in this project, only seven (five from OzClim and two Hadley Centre models) had a complete set of trends per degree of global warming, for all of the climate variables required in CCS, and did not require any infilling. The seven GCMs were: CSIRO-

Mk3.5, GISS-AOM, HADCM3, HADGEM1, INM-CM3.0, MIROC3.2(hires) and MIROC3.2(medres).

  - Trends in vapour pressure were not directly available from OzClim, so changes in specific humidity have been used to compute those.
  - Trends per degree of global warming for missing climate variables have been estimated (infilled) using suitable methods, and these are noted in the metadata.
- Trends per degree of global warming are computed from GCM monthly averaged data. They do not include information about changes in extremes, daily mean or variance.
- Trends per degree of global warming are spatially interpolated to higher resolution using bilinear interpolation. Topography is not taken into account, neither are any other factors. Thus, as no further information is added, small scale differences on small spatial scales may be deceptive.

10.7 Issues important to biological modelling

The initial scaling approach, using 'change factors', has several known limitations which need to be considered when applying the CF data to biological modelling. These limitations are important, since the application of a simple scaling approach can lead to unintended consequences in some biophysical models, especially those which are threshold dependant.

Users should note that uncertainty and errors in climate projections data can propagate from many sources, including:

- the underlying climate data;
- GCM models;
- spatial downscaling (from a coarse to fine grid); and
- temporal down scaling (i.e. from monthly to daily).

Furthermore, additional errors can occur when the computed climate projections data are then applied to biological models, due to:

- biology with inadequate functionality / parameterisation; and
- systems responses (management adaptation, natural selection / adaptation).

The following caveats, related to unrealistic outcomes that can occur with the OzClim 'change factor' approach, need to be considered in regard to the usage of 'change factors' and climate projections data based on these:

- In the underlying historical climate data, many stations may have a high degree of "patching" prior to 1957, in order to produce seamless data files back to 1889. The patching is based on spatial interpolation and other techniques (Jeffrey *et al*., 2001). The accuracy of patched data is lowest in isolated 'station poor' regions and is not improved in the 'change factor' based projections data.
- In the projections data, there is no change in the probability distribution function (PDF) of temperature, other than a uniform shift. However;
  - in reality some amount of change is likely in the PDF, which could lead to increased or decreased variability, and hence, a change in the frequency or high or low temperatures.

- A uniformly applied increase in minimum temperature may completely eliminate the occurrence of frost, at some locations, as:
  - complete elimination of frost may not occur in reality; and
  - this outcome could be unreasonable, since normal climate variability, even after global warming has occurred, is still likely to include a small probability of near/sub zero temperatures that would result in frost.
- In cases where a GCM shows a decreasing 21st Century trend in rainfall, a uniformly applied percentage decrease in rainfall may generate negative rainfall at some point in the future, particularly under a high emissions scenario, but this outcome is non-physical:
  - In initial Brian Pastures CF Version 0 test data, we found that the CSIRO-Mk3.5 GCM generated future projections (early in the 21st Century) containing negative rainfall under a high emissions scenario due to a rapid decline in rainfall per degree of global warming.
  - An analysis of other GCMs showed that this problem was widespread across Australia, especially in the drier months of the year.
  - To avoid this problem, in CF Version 1, we have truncated rainfall to a minimum 90% decline so it cannot ever be negative. The same constraint is applied to other climate variables that cannot be negative by definition. The application of these rules appears in the log warning ancillary files.
- While changes in daily rainfall intensity occur, the approach also assumes no change in the occurrence of the number of dry days, which would be important to germination/harvest and irrigation.
- Simultaneously applying simple changes to daily climate variables may, or may not, consistent. For example:
  - wet days tend to be associated with lower than average maximum temperatures, and dry days with higher than average maximum temperatures; and
  - a uniform increase in both daily rainfall and temperature may not fully capture this interdependence.

Other climate-related factors affecting biological response worth consideration are:

- The variability in the CO_2 responses of plants relative to climate warming sensitivities. The stabilisation of CO_2 will result in reduced changes in rainfall, temperature and soil moisture (Dai, Wigley, Meehl and Washington (2001));
- Changes in average wind speed, which may be an important for potential evaporation;
- Heat stress on growing points, especially close to ground surface;
- The effect of fire and flood on insects, pathogens, plant competition (e.g. weeds), trees relative to grasses. The responses for these may be unknown.
- Insufficient data on the impacts of extremes to correctly parameterise models. In some locations there may only be data for a single extreme event (i.e. damaging frost).

We recommend coupling the OzClim ‘change factor’ based projections data in the context of the broader range of current climate change risk assessment information.

11 Differences between CF and QM projections data, including versioning

Users should note that there are differences between the CF and QM climate projections data. The following discussion, including Tables 11.1 and 11.2, outline these differences.

11.1 GCMs, emissions scenarios, climate sensitivities and projections years

Differences between CF and QM Versions, related to available GCMs, emissions scenarios, climate sensitivities and projections years are listed in Table 11.1. The range of GCMs, emissions scenarios and climate sensitivities are described in Sections 7 and 8. Details on infilling of the missing trends per degree of 21st Century global warming for selected climate variables are provided in Section 9.

11.2 Historical baseline and training period

The CF projections data have not been de-trended in any way.

In the CF Version 1.1 projections, 'change factors' could be applied to daily data from 1889 to present. However, in considering applications model evaluation, we have since adopted the recommended use of a 1960 to 2010 baseline (which has been applied in the options for ordering CF Version 1.2 projections data via the web). The 1960 to 2010 baseline, as a default, is based on the improved quality of the historical data from 1960 onwards. Users should note that OzClim (CSIRO, 2010) uses a fixed 1975 to 2004 baseline.

All QM projections have been de-trended. In the QM projections, a 1957-2010 training period has been used to compute the perturbation rules that are applied to that historical baseline.

11.3 Latitude and longitude in file names

In the CF file names, station latitudes and longitudes which were rounded to two decimal places prior to August 2011 are now rounded to four decimal places.

11.4 Changes in SILO historical data

Regular updates and quality control measures are applied to the SILO climate database and some changes may affect both CF and QM projections data. For example, on 26 January 2012 there was a significant update to the SILO climate database, improving the precision of rainfall normalisation procedures. This update involved recalculation of normalisation parameters and an update to the station dictionary, affecting all variables within SILO. Furthermore, in CF Version 1.1 and 1.2, more accurate daily synthetic pan estimates have replaced the previous average daily pan evaporation values in APSIM files prior to 1970.

11.5 Quality control measures

Additional quality control measures were applied to each climate variable in the CF Version 1.1 and 1.2 data, over and above those applied in CF Version 1, so that application of change patterns

will not produce climate projections values outside the bounds of what may be reasonably expected. The additional quality control measures include clamping to calculated thresholds if:

- the projected vapour pressure is greater than the saturated vapour pressure at maximum temperature (reset to this value); and
- the projected solar radiation is greater than the maximum clear sky radiation for the day (reset to this value).

11.6 Calculation of pan evaporation

SILO can deliver a number of different estimates of potential evaporation. The historical data supplied in SILO files for APSIM (.met) and GRASP (.p51) consists of two estimates merged in time. Class A pan evaporation estimates either actual or in-filled by interpolated Class A pan is supplied for the period 1970 to current. Prior to widespread use of Class A pans in 1970, the SILO files contain a synthetic estimate of Class A pan based on monthly, spatially parameterised linear equations using vapour pressure deficit and solar radiation calibrated against actual pan measurements.

Estimates of pan evaporation under climate change are difficult, as only estimates of Morton's wet area evaporation (Morton, 1983) are available for a small subset of models. 'change factors' were previously applied to SILO baseline data in the initial CF V0 set. As this estimate of evaporation trends was for large water bodies and only available for a subset of GCM's it was decided not to use this 'change factor' and instead use 'change factors' for temperature, vapour pressure (from specific humidity) and solar radiation to compute an empirical equation to estimate a new synthetic pan estimate using the SILO spatial parameters (Rayner, 2005). While this was consistent with the pre-1970 synthetic pan data it introduced an inconsistency between the baseline SILO data set (which contains actual pan estimates post 1970) and the climate changed data which produced a synthetic pan estimate for this period. This inconsistency was eliminated in data sets supplied after July 2011 by applying the ratio of climate changed synthetic pan to baseline synthetic pan to the post 1970 actual pan data.

It should be noted that while synthetic pan is on average good proxy for measured pan, it is less variable due to lack of wind effects and does have areas of biases, but is much better than using long term average data for the pre 1970 period. In the future it is hoped to produce an improved synthetic pan estimate by incorporating wind run from GCM re-analysis data fields as an additional predictor variable.

11.7 Projected CF and QM means and standard deviations

To calculate the CF 2030 and 2050 projections, 'change factors' are applied uniformly to each of the historical daily datum. This means that while the means of the CF projected datum (i.e. for 2030 or 2050) will differ from the historical datum, the standard deviations of the CF projected datum will remain the same as that of the historical baseline data.

In calculating the QM 2030 projections, the method takes into account the variance implied by the target 2030 CDF (refer to Section 5.1). This means that we should expect changes in both the QM projected means and standard deviations.

In calculating the QM 2050 projections for rainfall and temperature, the method uses raw daily GCM data (refer to Section 5.2). This means that there will be changes in both the QM 2050 projected means and standard deviations. QM 2050 projections are limited to the ECHAM 5 GCM, A1B emissions scenario and median climate sensitivity. QM 2050 projections for vapour pressure,

pan evaporation and solar radiation are based on the QM 2030 method, using extrapolation of historical quantile trends to 2050, with renormalisation to the GCM mean by using 'change factors' with median sensitivity to global warming (refer to Section 5.2). This means that there will be changes in both the mean and the standard deviation of the projected datum.

11.8 Non-uniformity of perturbations

In the CF projections, perturbations are applied uniformly across the time series (within each month family). However, in the QM projections, the applied perturbations come from three sources, being:

1) the initial projection onto the target CDF
2) the transport of historical residuals from the projection trends to the projection
3) the final debiasing of the projected sequence to honour the OzClim trends.

Sources (1) and (3) are uniform, but source (2) is not. For example, a month that is abnormally low relative to its historical quantile trends may end up with negative perturbations after projecting. The likelihood of downward perturbations lessens as the projection year (or global warming) is increased, but the data will always be non-uniformly perturbed.

11.9 Differences between CF and QM projections

A comparison between CF and QM projections in summarised in Table1.1.

Table 11. 1 Comparison between 'change factor' (CF V 1.2) and 'quantile-matched' (QM) projections data.

Property	**Projections method**	
	'Change factor'	**'Quantile-matched'**
Applies shifts to the mean	Yes	Yes
Altered Cumulative frequency distribution	No	Yes, where p-value is significant
Applies changes to the standard deviation	No	Yes, where p-value is significant
Carries historical trends	Yes	Only if p-value not significant
Historical base line climate	1960 to 2010	1957 to 2010
Available projections years	2030 and 2050	2030 and 2050

11.9 Changes between QMV2.2.0 and QMV3.0

In 2014, an insignificant error was found in QM 2030 daily rainfall projections data produced by the QMV2.2.0 code, when developing the code for the QM with bootstrapping. Other climate variables were not affected. In testing the new QMV3.0 code, it was found that a small proportion of QMV2.2.0 generated data were affected, and only to an extremely minor extent (80 individual daily rainfall instances out of 912,500 days). Of those data, the average error in daily rainfall was 0.1 mm, with the largest error being 0.3 mm. Therefore, projections data based on both codes are almost identical. In fact, improvements to raw SILO climate data over time would more likely generate much larger changes.

Output based on the QMV3.0 code represents a slight improvement from that of QMV2.2.0, as it integrates the original QM methodology (outlined in Section 5 of this User Guide) with a modified QM method called 'Q5' that incorporates bootstrapping. Q5 is currently (as at May 2015) being developed for AR4, and then AR5 projections data. **The Q5 methodology is to be addressed in a separate CCS User Guide for AR5 projections data**.

11.10 Summary of differences between CF and QM versioning

The differences between CF and QM versioning are summarised in Table 11.2.

Table 11.2 Difference between Consistent Climate Scenarios projections data versioning.

Product	Version	Release date	Comments
'Change factor' (CF) data These files have no method tag.	V0	Apr 2010	Initial CF 2030 and 2050 projections test data for format checks, etc.
	V1	Sep 2010	Eight GCMs, eight emissions scenarios, three climate sensitivities, six climate variables and two projections years (2030 and 2050).
	V1.1	Apr 2011	Improvement over V1, including 17 GCMs, eight emissions scenarios, three climate sensitivities, six climate variables and two projections years (2030 and 2050). **The additional GCMs required more infilling for trends per degree of 21st Century global warming than the V1 set. Incorporates improved infilling techniques and additional diagnostic information.** Some improvements on evaporation. Historical baseline option 1899 to current.
	V1.2	Jun 2012	This is the version running under the web. Historical baseline 1960-2010. Includes two Hadley Centre GCMs(HADCM3 and HADGEM1). Otherwise, there is no difference in the data, from that of V1.1.
'Quantile-matched' (QM) data These files have a QM method tag in the filename.	QMV2.1.0 2030 **QM in filename**	Jun 2011	Initial 2030 test set.
	QMV2.2.0 2030 **QMv2.2 in filename**	Jul 2011	Initially 17 GCMs, eight emissions scenarios, three climate sensitivities, six climate variables and one projections year (2030). Two extra GCMs (HADCM3 and HADGEM1) added in June 2012.
	QMV3.0 2030 **2030 & QMv3.0 in filename**	May 2015	Code adjusted to fix a trivial error in QMV2.2.0, for which an insignificant amount of daily rainfall data had been affected and to negligible extent.
	QMV2.2.10 2050 **2050_QM2.2 in filename**	Nov 2011	Test set (2050 only), for a single GCM (ECHAM 5), one emissions scenario (A1B) and one climate sensitivity (median). Approach for 2050 rainfall and temperature projections uses daily GCM data. Projections for other climate variables based on QM 2030 method extended to 2050. 2050_QM2.2 in filename, but internally known as QMV2.2.10, to reflect different data.

12 Glossary

Agricultural Production Systems Simulator (APSIM)
An intensive grazing and crop modelling framework, used primarily to investigate the management of climate variability at a farm scale.

Amount of global warming
The estimated amount of global warming at a future point in time (i.e. 2050) occurring with a specified SRES emissions scenario.

AR3, AR4, AR5
International Panel for Climate Change (IPCC) Third, Fourth and Fifth Assessment Reports.

Australian Government Department of Agriculture, Fisheries and Forestry (DAFF)
An agency of the Australian Government, responsible for developing and implementing policies and programs that ensure Australia's agricultural, fisheries, food and forestry industries remain competitive, profitable and sustainable.

Australian Grassland and Rangeland Assessment by Spatial Simulation (AussieGRASS)
A leading Australian climate and biological modelling system run by the Department of Science, Information Technology and Innovation (DSITI), using advanced spatial simulation techniques and super computing facilities.
http://www.longpaddock.qld.gov.au/about/researchprojects/aussiegrass

Bureau of Meteorology (BoM)
An agency of the Australian Government, responsible for providing weather services to Australia and surrounding areas.

Carbon dioxide (CO_2)
A naturally occurring gas, which is also a by-product of burning fossil fuels and biomass, as well as land-use changes and other industrial processes. Changes in CO_2 concentrations have been linked to changes in the earth's temperature.

'Change factor'
The change in the climatological mean of a specific climate variable (e.g. temperature) between the current climate (defined in terms of a suitable 20th Century base period) and a projected time in the future (for example, the 30 years centred on 2050). 'Change factors' are based on the amount of global warming at a future point in time and the 21st Century pattern (or rate) of change.

'Change factor' (CF) approach
An OzClim based statistical approach, whereby monthly climate 'change factors' are used to scale historical climate data sets to produce daily climate projections for 2030 and 2050. The 'change factors' have been derived for a range of GCMs, emissions scenarios and climate sensitivities.

Climate Change Research Program (CCRP)
The DAFF Climate Change Research Program funds research projects and on–farm demonstrations to help prepare Australia's primary industries for climate change and build the resilience of our agricultural sector into the future.

Climate warming sensitivity
A simple measure of the strength of the effect of CO_2 concentrations on climate, particularly global temperature. In this project this term is expressed in terms of the uncertainty spread of the amount of global warming (under a specified SRES emissions scenario) at future point in time, i.e. 'low' (10^{th} percentile), 'median' (50^{th} percentile) or 'high' (90^{th} percentile).

Commonwealth Scientific and Industrial Research Organisation (CSIRO)
Australia's national science agency.

Consistent Climate Scenarios Project (CCSP)
A DAFF funded program formed to develop a consistent set of synthetic climate projections data across Australia for use in biophysical models, which maintain 'weather-like' properties and also account for uncertainties and biases in climate change projections, as well as different methods of downscaling.

Coupled Model Intercomparison Project Phase 3 (CMIP3)
The database formed by CMIP3 includes experiments from the 23 GCM models submitted to the International Panel for Climate Change (IPCC) Fourth Assessment Report (AR4).

Cumulative distribution function (CDF)
The cumulative distribution function gives the probability that an observation X is less than or equal to a given value x and gives the percentile (or quantile) rank of an observation.

Debiasing
Removal of systematic error.

Department of Environmental and Resource Management (DERM)
DERM handled environmental issues facing Queensland, including securing water for the future, managing land use, meeting the challenges of climate change, and conserving the state's natural and cultural heritage.

Department of Science, Information Technology and Innovation (DSITI)
Formed in February 2015, DSITI works closely with all agencies to drive the Queensland government's priorities in research, science, innovation, technology, intellectual property, service delivery.

Department of Science, Information Technology, Innovation and the Arts (DSITIA)
Formed in May 2012, DSITIA brought together science, information and technology, innovation and the arts in one portfolio to help drive Queensland's economy. The department was a critical enabler, to support tourism, agriculture, mining and construction. In February 2015, DSITIA transferred to DSITI.

Downscaling
The process of transforming numerical output from a coarse to a finer scale, i.e. from GCM model grid-point to regional scale.

El Niño
El Niño represents the warm phase of the El Niño–Southern Oscillation (ENSO) cycle (the opposite of a La Niña). This large-scale periodic warming of the central and central-east tropical Pacific results in changes in the atmosphere that affect weather patterns across much of the Pacific Basin, including Australia. During El Niño episodes the SOI is negative, due to lower-than-average air pressure at Tahiti and higher-than-average pressure at Darwin.

El Niño–Southern Oscillation (ENSO)
The coupled ocean-atmosphere phenomenon that produces year-to-year oscillations between opposite states of atmospheric pressure and rainfall, associated with the large-scale warming and cooling of the oceans in the central and east-central tropical Pacific. ENSO has three phases: warm (El Niño), cold (La Niña) and neutral. Common measures of ENSO are the Southern Oscillation Index (SOI) and Niño region ocean temperatures.

Emissions scenarios
Categorised outcomes, of greenhouse gas emissions, based on potential economic development, demographic and technological changes.

Ensemble
A group of realisations (runs) from a Global Climate Model (GCM).

Expert Review Panel
This panel provides expert scientific advice to the Consistent Climate Scenarios project.

File Transfer Protocol (FTP)
A protocol used for transferring files from one computer to another.

Global Climate Model (GCM)
A GCM is built on a sophisticated computer program, which uses mathematical equations, based on the physical laws governing the behaviour of the earth-climate system, to simulate the global climate. GCMs are used to produce climate projections for the 21st Century.

Grass Production Model (GRASP)
A pasture simulation and water balance model, specific to point locations, integrating climate, soil, plant, animal and management processes related to perennial grasses of Northern Australia. http://www.longpaddock.qld.gov.au/GRASP

Greenhouse Gases (GHG)
Natural and anthropogenic (man-made) gases in the atmosphere, that absorb and emit infrared or heat radiation, causing the greenhouse effect. The main greenhouse gases are water vapour (H2O), carbon dioxide (CO_2), nitrous oxide (NO) and methane (CH_4).

Interdecadal Pacific Oscillation (IPO)
The IPO, which has similarities to the Pacific Decadal Oscillation, is a slow background change in Pacific Ocean sea-surface temperatures, which fluctuates (between 'warm' and 'cool' phases) on an inter-decadal time scale and affects the relationship between the El Niño-Southern Oscillation (ENSO) and Queensland summer rainfall. During cool phases of the IPO, La Niña events tend to be more frequent during cool phases of the IPO. Phase-changes of the IPO occurred in 1909 to cool, 1922 to warm, 1945 to cool, 1978 to warm and 1999 to cool.

Intergovernmental Panel on Climate Change (IPCC)
The leading international body for the assessment of climate change, established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts.

La Niña
La Niña represents the cool phase of the ENSO cycle (the opposite of an El Niño) and is sometimes referred to as a Pacific cold episode. The large-scale periodic cooling of the central and east-central tropical Pacific results in changes in the atmosphere that affect weather patterns across much of the Pacific Basin, including Australia. During La Niña episodes the SOI is positive due to higher-than-average air pressure at Tahiti and lower-than-average pressure at Darwin.

Logit transformation
Used with logit regression, where the predicted values for the dependent or response variable will never be less than (or equal to) *0*, or greater than (or equal to) *1*, regardless of the values of the independent variables.

Long Paddock
An award-winning website, providing climate information and outlooks, to improve understanding and management of climate and variability in Queensland.

Model-ready
Data in a ready-to-use format (i.e. can be implemented into a modelling system without further adjustment).

Model realisation
A single run of a Global Climate Model (GCM).

OzClim™
A system containing patterns of regional climate change from a selection of Global Climate Models run by CSIRO and other research centres.

Patched point data
The term used where data that are either missing or suspect have been 'patched' with interpolated data.

Pattern of change
The projected mean annual rate of change for a particular climate variable per degree of 21st Century global warming.

Percentile
Percentiles are points taken at regular intervals from the cumulative distribution function (CDF) of a random variable, expressed as a percentage between 0 and 100. The sample 50th percentile is equivalent to the sample 0.5 quantile.

Perturb
To modify (i.e. scale).

Program for Climate Model Diagnosis and Intercomparison (PCMDI)
A research organisation in the USA, who's mission is to develop improved methods and tools for the diagnosis and intercomparison of GCMs that simulate global climate. The PCMDI archives the WCRP CMIP3 and CMIP5 Multi-Model Datasets.

Probability distribution function (PDF)
Like the, Cumulative distribution function, the PDF gives the probability that an observation X is less than or equal to a given value x and gives the percentile (or quantile) rank of an observation.

Quantile
Quantiles are points taken at regular intervals from the cumulative distribution function (CDF) of a random variable, expressed as a fraction between 0 and 1. The sample 0.5 quantile is equivalent to the sample 50th percentile.

Quantile-matching (QM)
QM maps historical values to projected values with the same quantile in each class.

Quantile-matching (QM) approach
QM is more sophisticated than the CF approach, in that it considers not only 'change factors' but also the projected changes in the cumulative distribution function of the climate projections.

Queensland Climate Change Centre of Excellence (QCCCE)
QCCCE existed from April 2009 to April 2012), as an Australian state-based climate science research centre within the Office of Climate Change, under DERM. DERM undertook targeted research to deliver specialised information to inform Queensland's response to climate change, climate variability and climate extremes. QCCCE provided information and science on climate change impacts, including the application of international research and science to the Queensland context. In May 2012, QCCCE transferred to DSITIA.

Scenario
A plausible description, but not a predication, of how the future may develop, based on a coherent and internally consistent set of assumptions about key relationships and driving forces, i.e. technological and economic change.

SILO
A climate database hosted by the Department of Science , Information Technology and Innovation (DSITI), containing Australian climate data from 1889 current to yesterday, in a number of ready-to-use formats, suitable for research and climate applications.
http://www.longpaddock.qld.gov.au/SILO

Special Report on Emissions Scenarios (SRES)
A report prepared by the Intergovernmental Panel on Climate Change (IPCC) for the Third Assessment Report (TAR) in 2000, on future emission scenarios to be used for driving global circulation models to develop climate change scenarios. The SRES Scenarios were also used for the Fourth Assessment Report (AR4) in 2007.

Stationarity
Stationarity occurs when the mean and variance of a statistic do not change over time.

Synthetic data
Best estimates, used as a proxy where either no or anomalous data exists.

Trend per degree global warming
The projected mean annual rate of change, for a specific climate variable, per degree of global warming.

13 References

Crimp, S., Kokic, P., McKeon, G., Smith, I. ,Syktus, J., Timbal, B. and Whetton, P. (2010). A review of appropriate statistical downscaling approaches to apply as part of Phase 2 of the Consistent Climate Projection project. CSIRO, National Research Flagships Climate Adaptation

CSIRO (2009). Glossary, retrieved May 23, 2011 from https://wiki.csiro.au/confluence/display/ozclim/Glossary.

CSIRO (2010). Welcome to OzClim – Exploring climate change scenarios for Australia. Retrieved May 23, 2011 from http://www.csiro.au/ozclim

Dai, A., Wigley, T., Meehl, G. and Washington, W. (2001). Effects of stabilizing atmospheric CO_2 on global climate in the next two centuries. *Geophysical Research Letters,* Vol. 28. No. 23, (pp 4511-4514).

Department of Science, Information Technology, Innovation and the Arts. Queensland Government. SILO Enhanced Meteorological Datasets, from http://www.longpaddock.qld.gov.au/silo/

Intergovernmental Panel on Climate Change (2000). *Special Report on Emissions Scenarios,* retrieved from http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf .

Intergovernmental Panel on Climate Change (2007). IPCC Fourth Assessment Report, retrieved May 23, 2011 from http://www.ipcc.ch/publications_and_data/ar4/wg1/en/spmsspm-human-and.html.

Jeffrey, S.J., Carter, J.O., Moodie, K.M and Beswick, A.R. (2001). Using spatial interpolation to construct a comprehensive archive of Australian climate data, Environmental Modelling and Software, Vol 16/4, pp 309-330.

Kokic, P., Jin, H. and Crimp S. (2012). Statistical Forecasts of Observational Climate Data. Extended Abstract, International conference on “Opportunities and Challenges in Monsoon Prediction in a Changing Climate” (OCHAMP-2012), Pune, India 21-25 February 2012.

Mitchell, J. F. B., T. C. Johns, M. Eagles, W. J. Ingram and R. A. Davis (1999). Towards the Construction of Climate Change Scenarios. Climatic Change 41(3): 547-581.

Mitchell, T. D. (2003). Pattern Scaling: An Examination of the Accuracy of the Technique for Describing Future Climates. Climatic Change 60(3): 217-242.

Morton F. (1983) "Operational estimates of areal evapotranspiration and their significance to the science and practice of hydrology", Journal of Hydrology, 66, 1-76.

NOAA (2010). Trends in Atmospheric Carbon Dioxide, retrieved July 21, 2010 from http://www.esrl.noaa.gov/gmd/ccgg/trends/#global_data

NOAA (2011). National Weather Service, Climate Prediction Centre. Cold & Warm Events by Season. Retrieved July 2011, from http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

Page, C.M. and Jones, D. (2001) 'OzClim: The development of a climate scenario generator for Australia.' In A. Zerger and R.M. Argent (eds.) MODSIM 2001 International Congress on Modelling and Simulation. (Modelling and Simulation Society of Australia and New Zealand). http://www.mssanz.org.au/MODSIM01/Vol%202/Page.pdf.

Panjkov, A. (2012 draft). Consistent Climate Scenarios Project: ‘Quantile-matching’ for climate projections. Department of Science, Information Technology, Innovation and the Arts. Queensland Government.

People & Place (2009). Glossary of Climate Adaptation and Decision-Making. (2009). Retrieved May 21, 2010, from http://www.peopleandplace.net/media_library/text/2009/5/19/glossary_of_climate_adaptation_and_decision-making

Program for Climate Model Diagnosis and Intercomparison (2011). About WCRP CMIP3 Model Output. Retrieved December 3, 2009, from http://www-pcmdi.llnl.gov/ipcc/info_for_analysts.php

Queensland Climate Change Centre of Excellence (2008 in preparation). AussieGRASS Environmental Calculator – Product Descriptions.

Queensland Climate Change Centre of Excellence (2009 in preparation). AussieGRASS Environmental Calculator & FORAGE – User Guide.

Rahmstorf, S. (2008). Anthropogenic Climate Change: Revisiting the Facts. In Zedillo, E. (PDF). Global Warming: Looking Beyond Kyoto. Brookings Institution Press. pp. 34–53 http://www.pik-potsdam.de/~stefan/Publications/Book_chapters/Rahmstorf_Zedillo_2008.pdf

Rayner, D.P. (2005). Australian synthetic daily Class A pan evaporation. Queensland Department of Natural Resources and Mines. Technical Report, December 2005, from http://www.longpaddock.qld.gov.au/silo/documentation/AustralianSyntheticDailyClassAPanEvaporation.pdf

Reichler, T., and J. Kim (2008), How well do coupled models simulate today's climate?. Bull. American Meteorological Society, **89**, 303-311

Reichler, T., and J. Kim (2008), Uncertainties in the climate mean state of global observations, reanalyses, and the GFDL climate model. Journal of Geophysical Research, vol. 113, D05106, doi:10.1029/2007JD009278, 2008

Ricketts, J.H. (2009). OzClim for the MTSRF region. 18th World IMACS/MODSIM Congress, Cairns, Australia 13-17 July 2009 http://www.mssanz.org/modsim09

Ricketts, J.H[a]., Kokic, P.N[b]. and Carter, J.O[a]. (2011). Estimating trends in monthly maximum and minimum temperatures in GCMs for which these data are not archived. [a]Queensland Climate Change Centre of Excellence, Queensland Government. [b]CSIRO, Mathematics, Informatics and Statistics. 19th International Congress on Modelling and Simulation (MODSIM), Perth, Australia 12-16 December 2011, http://www.mssanz.org.au/modsim2011/F5/ricketts.pdf

Ricketts, J.H[a]., Kokic, P.N[b]. and Carter, J.O[a]. (2013). Consistent Climate Scenarios: projecting representative future daily climate from global climate models based on historical data. [a]Department of Science, Information Technology, Innovation and the Arts. Queensland Government. [b]CSIRO, Mathematics, Informatics and Statistics, Australia. 20th International Congress on Modelling and Simulation (MODSIM), Adelaide, Australia, 1–6 December 2013, http://www.mssanz.org.au/modsim2013/L11/ricketts.pdf

Ricketts, J., and Page, C.M. (2007) 'A web based version of OzClim for exploring climate change impacts and risks in the Australian region.' In L. Oxley and D. Kulasiri (eds.) MODSIM 2007 International Congress on Modelling and Simulation. November 2007 (Modelling and Simulation Society of Australia and New Zealand). http://www.mssanz.org.au/MODSIM07/papers/10_s61/AWebBasedVersion_s61_Ricketts.pdf.

Schmidt M., Lipson H. (2009) "Distilling Free-Form Natural Laws from Experimental Data," Science, Vol. 324, no. 5923, pp. 81-85.

Smith, I. and Chiew, F. (2009). Document and assess methods for generating inputs to hydrological models and extend delivery of projections across Victoria. Final report for SEACI Phase 1 Project 2.2.5P. http://www.seaci.org/publications/documents/SEACI-1%20Reports/S1_FR225P.pdf

Suppiah, R., Hennessy, K.J., Whetton, P.H., McInnes, K., Macadam, I., Bathols, J., Ricketts, J., & Page, C.M. (2007). Australian climate change projections derived from simulations performed for the IPCC 4th Assessment Report. Aust. Met. Mag. 56 (2007) 131-152. CSIRO Marine & Atmospheric Research, Australia.

US National Academies (2010, prepublication copy). Climate Stabilization Targets: Emissions, Concentrations, and Impacts over Decades to Millennia. Committee on Stabilization Targets for Atmospheric Greenhouse Gas Concentrations - Board on Atmospheric Sciences and Climate Division on Earth and Life Studies. The National Academies Press. Washington, D.C. http://www.nap.edu/catalog/12877.html

Watterson, I.G. (2011). Understanding and partitioning future climates for Australian regions from CMIP3 using ocean warming indices. *Climatic Change*.

Whetton, P. H., R. N. Jones, K. L. McInnes, K. J. Hennessy, R. Suppiah, C. M. Page, J. Bathols and P. J. Durack (2005). Australian climate change projections for impact assessment and policy application : a review P. H. Whetton *et al* . Series: CSIRO Marine and Atmospheric Research paper,1. Aspendale, Vic.

Wigley,T.M.L., Raper,S.C.B., Hulme,M. and Smith,S. 2000. The MAGICC/SCENGEN Climate Scenario Generator: Version 2.4, Technical Manual, Climatic Research Unit, UEA, Norwich, UK, 48pp.
Wigley, T.M.L., Richels, R, & Edmonds, J.A. (1996). Economic and environmental choices in the stabilization of atmospheric CO_2 concentrations. *Nature* 379, 240 - 243.

Wikipedia (2010). Special Report on Emissions Scenarios. Retrieved May 24, 2010, from http://en.wikipedia.org/wiki/Special_Report_on_Emissions_Scenarios

World Meteorological Organization. (2008) Guide to Meteorological Instruments and Methods of Observation, Appendix 4B, WMO-No. 8 (CIMO Guide), Geneva 2008.

14 Contact details

Feedback about the contents of this document is encouraged and most welcome. All comments related to this document, including data access and data derivation, should be directed to cccs@dsitia.qld.gov.au

15 Appendix

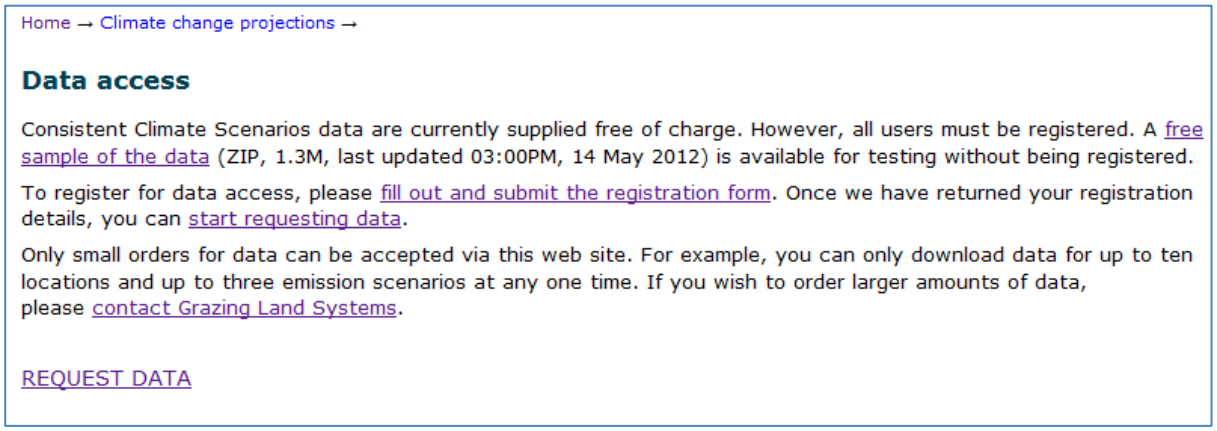
DAFF Climate Change Research Program Projects

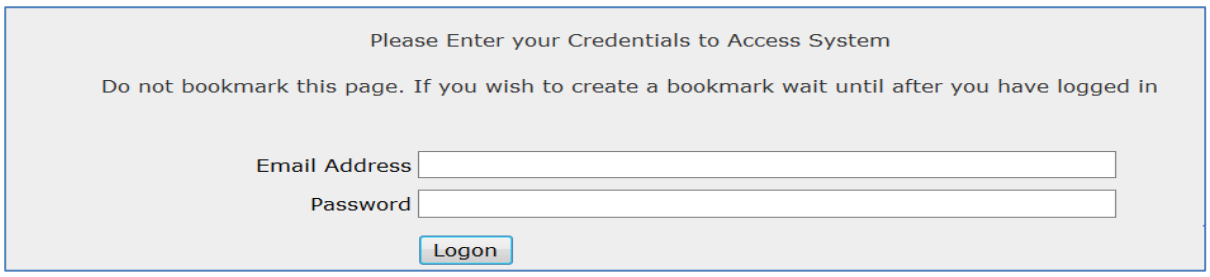
- A national research program for climate ready cereals – performance of wheat and sorghum under current and future climates (CSIRO)
- Adaptation of a range of wheat types to elevated atmospheric CO_2 concentration (University of Melbourne)
- Developing climate change resilient cropping and mixed cropping/grazing businesses in Australia (CSIRO)
- Relocation of intensive crop production systems to northern Australia: Costs and opportunities (DEEDI, Qld)
- Agriculture transforming to adapt to climate change: Peanut industry expansion in the NT as a blueprint (CSIRO)
- Development of effective management strategies to adapt production to mitigate climate change challenges in the wine industry Grape and Wine Research and Development Corporation (GWRDC)
- Developing improved on-ground practices and institutional policies for managing climate variability and climate change within beef production enterprises across northern Australia (DEEDI, Qld)
- Climate Change Adaptation in the Southern Livestock Industries (Meat & Livestock Australia)
- Amelioration of thermal stress impacts on animal performance and welfare in southern Australian dairy, beef and sheep industries (University of Melbourne)
- Adaptation of fisheries and fisheries management to climate change in south-eastern Australia – a national case study (DPI, Vic)
- Consistent Climate Scenarios (QCCCE/DSITIA, Qld)

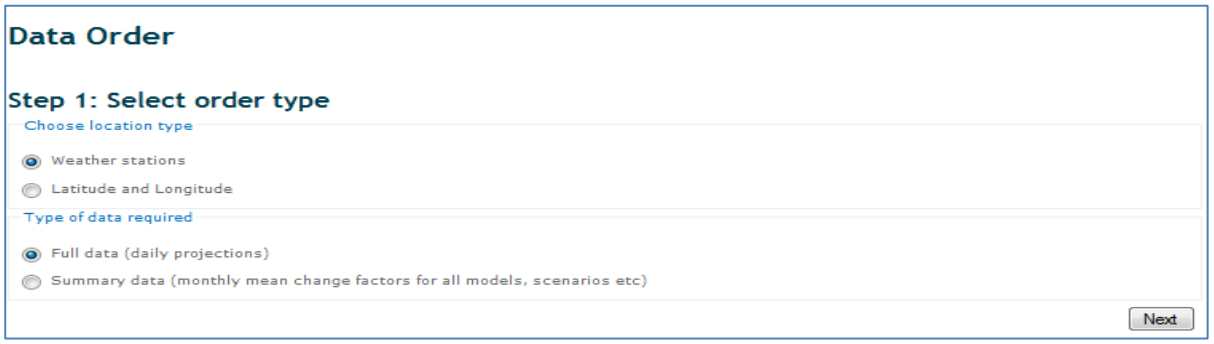
Consistent Climate Scenarios – Web Portal

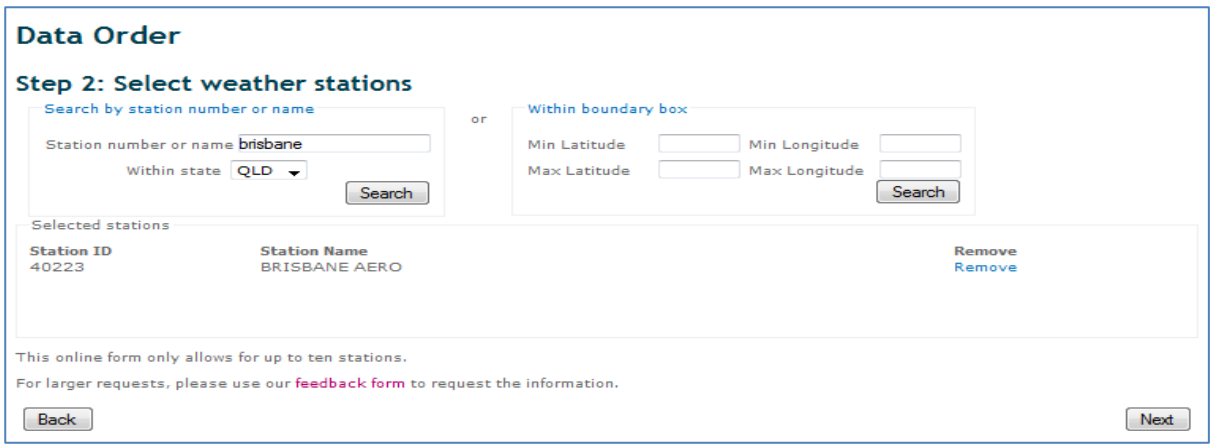
http://www.longpaddock.qld.gov.au/climateprojections/access.html

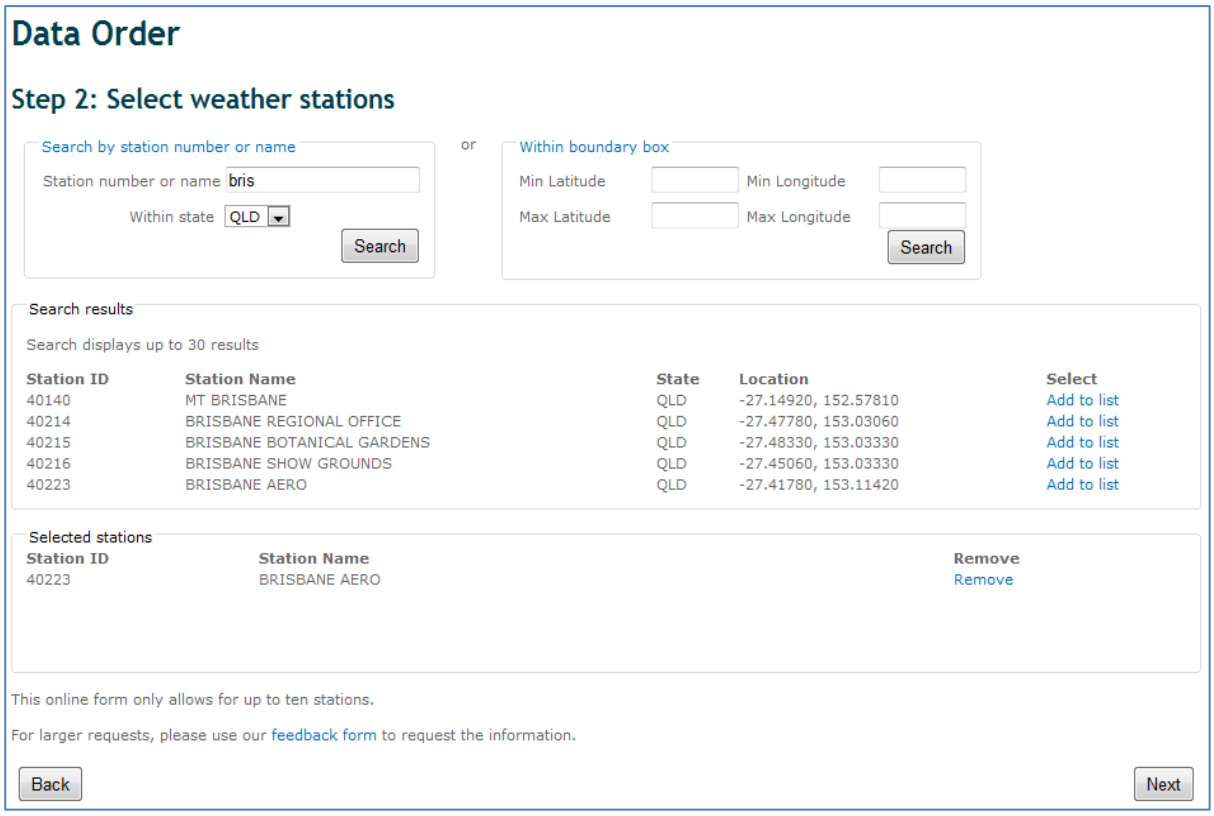
This example shows the process required to order 2030 daily projections data for Brisbane Airport, based on the Change Factor method, using the UKMO-HadGEM1 GCM forced by the A1FI emissions scenario with medium climate warming sensitivity.

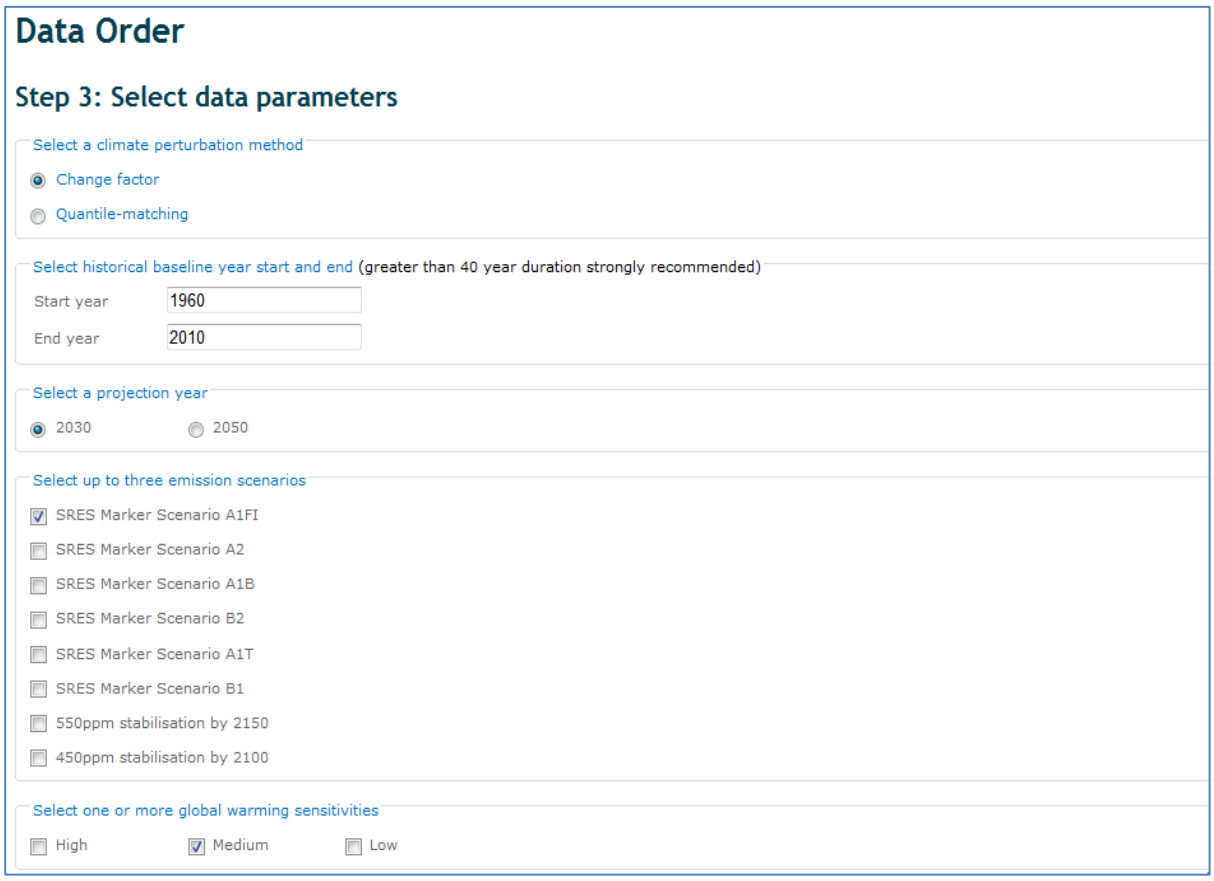

Home → Climate change projections →
Data access
Consistent Climate Scenarios data are currently supplied free of charge. However, all users must be registered. A free sample of the data (ZIP, 1.3M, last updated 03:00PM, 14 May 2012) is available for testing without being registered.
To register for data access, please fill out and submit the registration form. Once we have returned your registration details, you can start requesting data.
Only small orders for data can be accepted via this web site. For example, you can only download data for up to ten locations and up to three emission scenarios at any one time. If you wish to order larger amounts of data, please contact Grazing Land Systems.
REQUEST DATA


Please Enter your Credentials to Access System
Do not bookmark this page. If you wish to create a bookmark wait until after you have logged in
Email Address
Password
Logon






Data Order
Step 2: Select weather stations
Search by station number or name
Station number or name bris
Within state QLD
Search
or
Within boundary box
Min Latitude
Min Longitude
Max Latitude
Max Longitude
Search
Search results
Search displays up to 30 results
Station ID Station Name State Location Select
40140 MT BRISBANE QLD -27.14920, 152.57810 Add to list
40214 BRISBANE REGIONAL OFFICE QLD -27.47780, 153.03060 Add to list
40215 BRISBANE BOTANICAL GARDENS QLD -27.48330, 153.03330 Add to list
40216 BRISBANE SHOW GROUNDS QLD -27.45060, 153.03330 Add to list
40223 BRISBANE AERO QLD -27.41780, 153.11420 Add to list
Selected stations
Station ID Station Name Remove
40223 BRISBANE AERO Remove
This online form only allows for up to ten stations.
For larger requests, please use our feedback form to request the information.
Back
Next

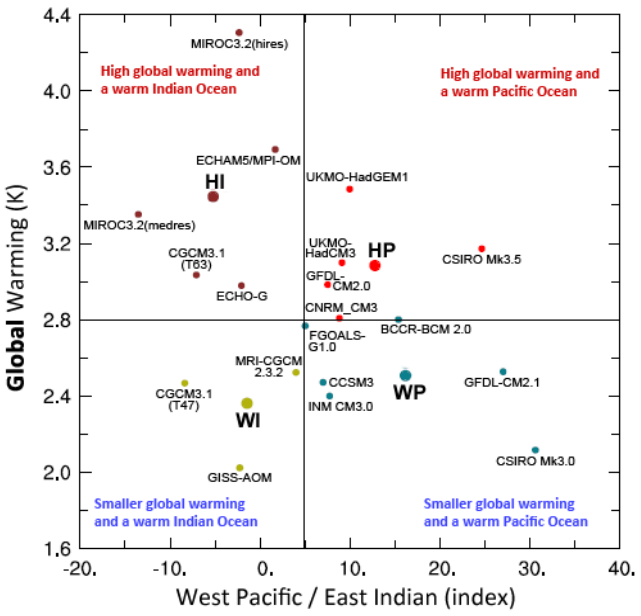

Data Order
Step 3: Select data parameters
Select a climate perturbation method
Change factor
Quantile-matching
Select historical baseline year start and end (greater than 40 year duration strongly recommended)
Start year 1960
End year 2010
Select a projection year
2030
2050
Select up to three emission scenarios
SRES Marker Scenario A1FI
SRES Marker Scenario A2
SRES Marker Scenario A1B
SRES Marker Scenario B2
SRES Marker Scenario A1T
SRES Marker Scenario B1
550ppm stabilisation by 2150
450ppm stabilisation by 2100
Select one or more global warming sensitivities
High
Medium
Low

Data Order

Step 3: Select data parameters

Climate models

Models HI, HP, WI and WP are composites of the four mean climate response patterns below.



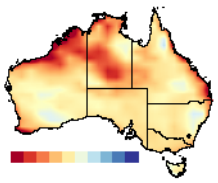
Adapted from Watterson (2011)

Select one or more Global Climate Models

- [ ] UKMO-HadCM3
- [ ] MIROC3.3(hires)
- [ ] GFDL-CM2.1
- [ ] GFDL-CM2.0
- [ ] MIROC3.2(medres)
- [ ] ECHO-G
- [x] UKMO-HadGEM1
- [ ] ECHAM5/MPI-OM
- [ ] MRI-CGCM2.3.2
- [ ] CCSM3
- [ ] CGCM3.1(T63)
- [ ] GISS-AOM
- [ ] INM-CM3.0
- [ ] CGCM3.1(T47)
- [ ] FGOALS-g1.0
- [ ] CSIRO-Mk3.5
- [ ] CSIRO-Mk3.0
- [ ] CNRM-CM3
- [ ] BCCR-BCM2.0
- [ ] HI - Composite

Maps represents the mean change in the climate variable (i.e. increase/decrease) per degree of 21st Century global warming, using the specified GCM

Rainfall



UKMO-HadGEM1

Developed at the Hadley Centre for Climate Prediction and Research, Met Office (UKMO), United Kingdom; 38 atmospheric levels and 40 ocean layers; Well-mixed greenhouse gases, ozone, direct and indirect sulphates, black carbon, organic carbon, land-use, solar irradiance and volcanic aerosols; **CCS Expert Panel assessment**: More likely to produce credible projections

Data Order

Step 4: Delivery details

Provide a unique label for your data files

CFtest — Up to eight characters

Select the type of operating platform for your file format

- (•) Windows
- ( ) UNIX

Select the output file format

- (•) APSIM
- ( ) P51

Should diagnostic charts be included in the output data file package

- (•) No
- ( ) Yes

Delivery method

I wish to receive my order by

- (•) FTP
- ( ) Delivery by post

Delivery or notification address

Back — Next

Data Order

Step 5: Confirm order

Please confirm and submit your order

```
1 weather stations selected.
                        40223 BRISBANE AERO
Perturbation method   : Change factor
Baseline              : 1960-2010
Projection year       : 2030
Emission scenarios    : SRES Marker Scenario A1FI
Warming sensitivities : Medium
Climate models        : UKMO-HadGEM1
```

Data file details

```
Data file label:        CFtest
Platform:               Windows
Output format:          APSIM
Include charts:         No
Delivery method:        FTP
```

```
Estimated size of your order is : 1 Mb
Estimated processing time is    : 24 hours.
```

Back Submit

Data Order

Order confirmation

Thank you, your order has been received.

You can view your order and check on its progress at View your orders
If you would like to place a further order click here. Create a new order

Subject: CCCS Data Order job number its682

Thank you for ordering Consistent Climate Scenario Data through the Long Paddock website.

Your order number its682 and unique job label QMtest is now ready for download at ftp://climate-scenarios.mft.derm.qld.gov.au/Climate_Scenarios/CCCS_Web_Data_Outputs/stuart.burgess.
The data will be removed from the FTP server in 7 days.

The user guide and other supporting documents are available at ftp://climate.mft.derm.qld.gov.au/Climate_Scenarios/Documentation.

Please note: If an error message appears when attempting to download data from the FTP server it may be that your web browser is operating behind an institutional firewall which could be interfering with the file transfer process. Use of a third party FTP client such as 'FileZilla', with a fuller range of FTP options, may overcome such difficulties.

If you experience unresolved difficulties with accessing information from the FTP server please contact:

Stuart Burgess (DSITI)
Ph: 07 3170 5528
Email: stuart.burgess@science.dsiti.qld.gov.au
The Consistent Climate Scenarios Data was developed by the Queensland Department of Science, Information Technology and Innovation under funding from the Department of Agriculture, Fisheries and Forestry's 'Australia's Farming Future - Climate Change Research Program' (http://www.daff.gov.au/climatechange/australias-farming-future/climate-change-and-productivity-research)